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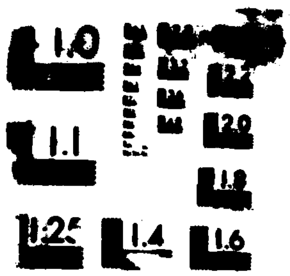

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ISSUE 1

ROYAL AIRCRAFT ESTABLISHMENT

ISSUE 1

RAE TECHNICAL MEMORANDUM FS(F) 510

RECOMMENDED TEST SPECIFICATION FOR THE ELECTROMAGNETIC COMPATIBILITY OF AIRCRAFT EQUIPMENT

by

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NOVEMBER 1985

SUMMARY

This memorandum is the result of the activities of the MOD(PE) Specifications Sub-group of the MOD(PE) Aircraft EMC Co-ordinating Committee consisting of representatives of A&AEE, DAES and RAE. It is based on knowledge gained from research on EMC test procedures and will be continuously updated in the light of any future research and test experience. It should be used to form the basis of any future aircraft project EMC specifications with suitable tailoring to meet specific requirements with the formal approval of the Project Director.

CONTENTS

LIST OF FIGURES

1 INTRODUCTION

This document specifies the test limits and test methods for measurement and determination of the electromagnetic interference characteristics (emission and susceptibility) of the electrical, electronic, and electromechanical equipments to be procured for use in military aircraft. Tests specific to the performance of transmitting and/or receiving equipment are not included in this specification, and will have to be separately specified in the equipment's technical specification.

The requirements specified are established to ensure that EMC is considered in the design of the equipment, and to provide confidence that compatible operation of the equipment will result when it is installed in the aircraft and used operationally. It also provides the criteria by which contractual requirements can be shown to have been met and information to help in the clearance of the final aircraft.

This specification may be used as a basis for new project specifications within Air System Controllerate (ASC) and will require to be tailored to meet individual project requirements, with the formal approval of the Project Director.

2 PRECEDENCE OF REQUIREMENTS

In any conflict of requirements between this document and the equipment's technical specification the latter shall take precedence.

3 FORMAT

The test methods contained in this document are designated by an alpha-numeric identification scheme. Each method is identified by a three letter combination and a two digit number.

ACE - Conducted Emission
ACS - Conducted Susceptibility
ARS - Radiated Susceptibility
ARE - Radiated Emission

Each test method in this document is divided into sub-sections of Purpose, Applicability, Test Layout, Test Method and Test Limits followed by relevant illustrations.

4 REFERENCES

The following documents have been used as a basis for some of the test methods included in this document.

1 MIL-STD-461A, Notices 1, 2, 3 and 4.
Electromagnetic Interference Characteristics
Requirements for Equipment

2 MIL-STD-462, Notices 1, 2 and 3.
Electromagnetic Interference Characteristjcs
Measurement of.

3 MIL-STD-463
Definitions and Systems of Units, Electromagnetic Interference Technology.

4 BS 3G100, Part 4, Section 2, 1980.

5 BS 3G100, Part 3.

6 Panavia Specification SP-P-90001.

7 Panavia Specification SP-P-90003.

8 Boeing Specification D6-16050.

9 Draft International Standard ISO-DIS-2677.

10 EHI Specification EA98Q010J.

11 RAE Technical Memorandum FS(F)442.

12 RAE Technical Memorandum FS(F)457, 550,588 and 613.

5 TEST APPLICABILITY AND LIMITS

5.1 Applicability

A selection of tests from Table 1 as applicable shall be agreed with the technical authority, included in the equipment specification, and form the basis for the EMC Test Plan.

Table 1

Test Number	Definition of Test
ACE 01	Power Leads, Conducted Emissions, 20 Hz to 150 MHz
ACE 02	Control and Signal Leads, Conducted Emissions, 20 Hz to 150 MHz
ACE 03	Power Leads, Exported Transients
ACS 01	Power Leads, Conducted Susceptibility, 20 Hz to 50 kHz
ACS 02	Power Control and Signal Leads, Conducted Susceptibility, 50 kHz to 400 MHz
ACS 03	Control and Signal Leads, Conducted Susceptibility, 20 Hz to 50 kHz
ACS 04	Power Control and Signal Leads, Imported Transients
ARE 01	Magnetic Field, Radiated Emission, 20 Hz to 50 kHz
ARE 02	Electric Field, Radiated Emissions, 50 kHz to 18 GHz
ARS 01	Magnetic Field, Radiated Susceptibility, 20 Hz to 50 kHz
ARS 02	Electric Field, Radiated Susceptibility, 50 kHz to 18 GHz

5.2 Limits

It is impossible to define a set of test limits which will apply to all situations. They depend on the sensitivities of the onboard receiving equipment, the power and frequencies of the onboard transmitters, the external environment in which the aircraft will operate and the type of construction and materials used for the airframe. The suggested limits will meet most normal situations but should be reviewed and tailored where necessary for each application.

6 GENERAL TECHNICAL ADVICE AND INFORMATION

6.1 Introduction

This section is common to all tests in Sections 7 and 8. Any extra details specific to a particular test will be given in the appropriate section.

6.2 Shielded Enclosure

Ideally all EMC qualification tests should be made in a shielded enclosure which provides a rf quiet zone screened from broadcast and other emitting sources, and in which high rf field can be generated without causing interference to other users of the rf spectrum.

The shielded enclosure shall be of sufficient size to accept the EUT and test antennas without requiring deviation from the methods specified in this document.

The shielding effectiveness to electromagnetic field shall be sufficient to provide ambient electromagnetic levels at least 6 dB below the limit curve of each test to be performed in the enclosure.

At higher frequencies the effects of cavity resonances and wall reflections may be reduced by the use of some rf absorber material and so aid the production of repeatable results.

The test area shall be cleared of all items not pertinent to the radiated emission and susceptibility tests in order to reduce any effect they may cause on the measurement. This includes all unecessary test equipment, cable racks, storage cabinets, desks, chairs etc. Personnel not actively involved in the test should be excluded from the shielded enclosure. The purpose of this requirement is to reduce antenna loading effects of nearby objects, changes in multiple reflections within the enclosure due to changes in nearby objects and personnel locations, emissions from non EUT equipments, and to reduce interactions from other unconnected activities.

This can be achieved by housing all the equipment other than the equipment under test (EUT) in another area and coupling to the EUT by an access panel fitted with bulkhead coaxial connectors and filters as shown in Figure 1. Observation of the EUT can then be made using a suitably rf hardened TV camera coupled via a fibre optic link to a monitor.

6.3 Ground Plane

In order to provide a reference plane, the equipment under test shall normally be mounted on a solid-plate metallic ground plane having minimum thickness of 0.25 mm for copper, 0.5 mm for aluminium (non-preferred because of oxidization) and 0.63 mm for brass, with a minimum areas of 2.25 m^2 and a minimum side of 0.75 m. The ground plane shall be bonded to the walls, solid sheet bonds being preferred, the bonds being not more than 0.9 m apart. The maximum d.c. resistance between the ground plane and the walls shall not exceed 2.5 milliohms.

For large equipment mounted in a metal rack or cabinet, the metal rack or cabinet shall be considered a part of the ground plane for testing purposes and shall be bonded to the ground plane by the rack or cabinet bonding arrangements.

6.4 Power Supplies

Adequate power supplies shall be provided to the shielded chamber to enable the EUT to be operated at full load with the normal supply voltage at its input terminal.

Filtering of the power supply must be such that the resulting voltage at the EUT is at the nominal value throughout the load variation of the EUT. The degree of filtering must reduce any interference in the circuit under test by at least 6 dB below the test limit. Filtering of instrumentation supplies for screened rooms must also be adequate so that any interference entering the room by this path is 6 dB below the limit in the test circuit.

6.5 Line Impedance Stabilisation Networks (LISN)

In order to eliminate possible differences in power supply impedance at the different EMC Test Houses, and to provide a defined impedance into which the interference current can be measured, a LISN shall be included in all power supply leads to the EUT.

The circuit diagram of the LISN's shall be as shown in Figure 2, further design details are given in RAE Technical Memorandum FS(F)613.

The characteristics for the line impedance stabilisation network shall be as shown in Figure 3 when loaded with a 50 ohm termination at the measuring set terminal and with the supply or load terminal shorted to the case.

The measuring set terminal of the LISN shall be terminated by a 50 ohm non-reactive load. This load needs to have a rating of 50 W for the ACS 02 test.

A 10 uF feedthrough capacitor shall be connected on the supply side of the LISN, being bonded to the ground plane.

When used on d.c. power supplies an additional 30,000 uF capacitor shall be connected between positive and negative in the power supply side of the LISN to improve its low frequency performance. Figure 4 shows protection circuitry which may be required to reduce switch-on surges. A bleed resistor should be connected across the capacitor.

The LISN's may be permanently connected to the power supplies and used in all tests detailed in this specification.

6.6 Instrumentation and Equipment Under Test Isolation

When performing electromagnetic emission and susceptibility measurements it is important to consider unintentional conduction routes for interference.

The EUT and EMI measuring instrumentation and any Special to Type Test Equipment (STTE) shall each derive power from sources with adequate isolation. This may be achieved by the use of separate shielded room power supply filters.

An alternative or additional method shall be by connecting the EMI receiver to its a.c. power source via a Faraday-shielded isolation transformer. The purpose is to break the chassis power ground to prevent the circulation of ground currents in the loop.

6.7 Layout of the Equipment Under Test

To ensure a measure of repeatability in EMI Testing, the EUT must be laid out within certain confines. It is desirable that the face of the EUT with the highest emission shall be positioned 0.10 m $^{+}/_{-}$ 0.02 m from and parallel to the front edge of the ground plane. When the EUT consists of more than one item, their faces shall be aligned in a straight row and positioned 0.10 m +/_ 0.02 m from the parallel to the front edge of the ground plane, unless the relative positions of the units to each other in the aircraft are known. If the aircraft positions are known then the EUTs shall be positioned as near as possible to simulate this situation. If the rack for a mounted EUT is available then this shall be utilised for the test. Figure 5 shows a suggested set-up for multiple equipment units.

Photographs or detailed sketches of the test layout shall be included in the EMC Test Report.

6.8 Arrangement and Length of the Equipment Under Test's Leads

The EUTs power leads and interconnecting cableforms shall whenever possible be of the length, type and lay-up representative of the aircraft installation, and ideally aircraft cableforms should be used. They shall be supported above the ground plane on 50 mm insulated stand-offs (e.g. Styrofoam). The purpose of this is to simulate the ground-current loop area of a typical installation. If the leads were located directly on the ground plane this would result in lower magnetic-field emissions or susceptibility and hence give more favourable test results. This requirement relates to the fact that aircraft installations cannot always allow wiring harnesses or cables to be clamped directly to the vehicle structure over the whole of the cable length.

When the aircraft cableform is not known control and signal cable lengths shall be 2 metre $^{+}/_{-}$ 0.1 m. Primary power lines shall always be 1 metre $^{+}/_{-}$ 0.1 m.

When the length of an interconnecting cableform between two items of an EUT is greater than 2 m, the leads must be deployed in a certain manner. The cableform should be arranged as shown in Figure 5 with the excess length zig-zagged at the back of the test bench on 50 mm supports. This method is preferred to that of coiling the cable as coiling would increase the cable inductance by as much as ten times for a very long cableform thus reducing the conducted emissions. Some installations require very long cable runs and this cannot be accommodated on the test bench; therefore the maximum length of interconnecting cableforms is restricted and shall not exceed 15 m. Duplication of an actual installation cableform shall be considered the ideal representation.

Ideally the run of cable should follow the front edge of the test bench at a distance of 100 mm from the edge for at least part of the length. This will not always be possible due to the relative positions of front face of the EUT and connector dispositions. The positions and length of cables must be recorded in the test report.

6.9 Bonding of Equipment Under Test

The provisions included in the design of the EUT and specified in the installation instruction shall be used:

(a) to bond the EUT items together, such as equipment case and mount, and/or

(b) to bond the EUT to the ground plane.

When used, bonding jumpers and routing shall be as close as possible to those specified for the installation including the method of connection.

Equipments intended to be grounded through a third wire should be grounded via that method unless a special installation requires otherwise. When this metnod is used the EUT shall be placed on an insulating mat.

When EUT's are secured to mounting bases having shock or vibration isolators, bonding straps when furnished with mounting bases, shall be connected to the ground plane. If bonding straps are not specified none shall be fitted.

Portable equipment shall not be bonded to the ground plane during testing unless this is required by the installation specification. Portable equipment that is grounded through the power cable shall not be bonded to the ground plane but shall be mounted on insulating material 50 mm above the ground plane.

When an external terminal lug, stud or connector pin is available for a ground connection on the EUT, it shall be used if normal installation so indicates. When the installation is unknown, the ground terminal or pin shall not be used.

Details of the EUT bonding shall be included in the Test Report.

6.10 EUT Interface Loads and Test Jigs

Ideally the EMC test should be performed on a complete system or sub-system.

EUTs interfacing with other units, which for practical reasons are not part of the EUT, shall be suitably loaded. The loads may be electrical, electronic, and/or mechanical, as applicable. Electrical/electronic loads should simulate the impedance of the actual load as far as is practical. Care should be taken to ensure that any active loads do not contribute to the overall emission or susceptibility characteristics of the EUT. This may be achieved by shielding the load, filtering the inputs/outputs or remotely siting the loading in an ante-room to the shielded enclosure.

6.11 Excitation of Equipment Under Test

In addition to the requirements of Paragraph 6.10 the following consideration shall be made.

When practically possible, the EUT shall be exercised by the same means as in the actual installation. For example, if a solenoid or relay is to be activated by a thyristor or SCR circuit, do not use a toggle switch to operate the solenoid or relay. Voltage and/or current regulators and other circuits which function intermittently shall be exercised during the test, as described in the EMC Test Plan, to simulate real-life conditions.

The selection of the operating conditions for a EUT must be considered carefully to encompass the most emissive and most susceptible conditions.

6.12 Ambient Electromagnetic Levels

The ambient electromagnetic interference levels shall be measured prior to commencement of test as indicated below and shall be at least 6 dB below the allowable limits. The number of ambient noise measurements made may be reduced if a number of tests are made consecutively. Details to be included in the test report.

For methods involving the measurement of conducted emissions on the EUT's power leads, the power leads shall be disconnected from the EUT and the EUT replaced by a non-inductive resistance load. The value of this load shall be such that the same current is drawn from the power source as when the EUT is connected.

For methods involving the measurements of conducted emissions on interconnecting cableforms, the EUT shall be de-energised and the EUT monitoring equipment/test set shall be energised.

For methods involving the measurement of radiated fields, the EUT shall be de-energised and the EUT monitoring equipment/test set shall be energised.

One method to achieve the requirement of this section is to adopt the shielded enclosure ante-room arrangement as described in section 6.2 with provisions made for bulkhead filtering of the EUT monitoring equipment/test set to EUT interconnecting cableforms.

6.13 EMI Receivers

The EMI Receiver used to perform the applicable test methods shall have sufficient sensitivity to enable measurements of the parameters of the EUT to at least 10 dB below the limits detailed in this specification.

These receivers shall have the following tolerances, unless otherwise stated in a particular test:

Frequency - accuracy shall be $^+/_-$ 2 percent of indicated frequency.

Amplitude - accuracy shall be $^+/_-$ 2 dB (for CW signals) and $^+/_-$ 3 dB (for impulse signals) of the indicated value.

The EMI receivers shall be calibrated under a system approved by MOD(PE).

The EMI receivers shall incorporate a peak detector (calibrated in terms of the RMS value of an equivalent sine-wave and responding to true peak values) which shall be used for all measurements.

The EMI receivers shall have means of producing an output of amplitude and frequency to enable X-Y plots to be obtained (see Paragraph 6.21).

The nominal input impedance of the EMI receivers shall be 50 ohm.

The use of spectrum analysers at frequencies below 1 GHz is restricted to susceptibility testing due to overload problems which may arise from lack of front end preselection. If adequate front end tracking preselection is provided and adequate sensitivity available, then unrestricted use including emission testing may be permitted following consultation with the Technical Authority.

6.14 Measurement Bandwidths

One of the most troublesome areas in EMC testing is the classification of measured interference emissions as either narrow or broadband. In a MIL-STD-462 Application Note (ASD/ENA-TR-80-3) a procedure was suggested whereby only one bandwidth is used in each receiver band eliminating some of the difficulties in determining the appropriate classification of noise.

Ideally this bandwidth is chosen such that a broadband signal at the broadband limit at a particular frequency will develop the same voltage in the receiver bandpass as a narrowband signal at the narrowband limit.

In this standard there are no separate narrow and broadband limits as this distinction in interference types is artificial, depending on the measurement bandwidth and has lead to many problems in the past. Instead for each emission test the following bandwidths only shall be used.

Frequency Band	Impulse Bandwidth
20 Hz - 1 kHz	10 Hz $^+/_-$ 5 Hz
1 kHz - 50 kHz	100 Hz $^+/_-$ 50 Hz
50 kHz - 1 MHz	1 kHz $^+/_-$ 100 Hz
1 MHz - 30 MHz	10 kHz $^+/_-$ 1 kHz
30 MHz - 18 GHz	100 kHz $^+/_-$ 10 khz

The use of these bandwidths is to be confirmed in the Test Report.

Care must be taken to ensure that the measuring receiver or analyser is not overloaded by broadband signals.

6.15 Current Probes

(i) Emission testing

The current probes used during the tests described in this standard must have adequate sensitivity, i.e. transfer impedance and must be capable of carrying the rated d.c. or power frequency current without saturation. The probe winding shall be electrostatically screened.

(ii) Susceptibility testing (rf)

The injection probes used during the tests described in this standard must comply with the particular requirements stated in each test method. During the high level cw rf injection tests prolonged excitation will cause a significant temperature rise of the probe and due care must be exercised to avoid damage to the cable under test. Information on design details and performance of these probes is given in RAE Technical Memorandum FS(F)588.

6.16 VSWR of Instrumentation

Over the frequency range of concern for any given test, the VSWR of resistive dummy loads, attenuators, directional couplers, samplers, power dividers and like networks shall not exceed 1.3:1.

6.17 Signal Sources/Power Amplifiers

The signal source used for susceptibility testing must be capable of modulation as described in para 6.23. The low frequency square wave modulation can be achieved by a series electronic switch between the signal generator and the power amplifier.

The harmonic content of the signal source/power amplifier can cause erroneous results and care should be taken to minimise harmonics. Where particular difficulty is experienced, low pass filters may have to be used in the power amplifier output.

6.18 Oscilloscope and Probes

The oscilloscope shall be such that it records the levels and waveforms of both fast and slow transients as required by the test limits. The use of a long persistance or memory type of oscilloscope is recommended.

The oscilloscope shall have a differential input amplifier with balanced oscilloscope probes such that the common mode rejection ratio (CMRR) at the probe tips shall be greater than 30 dB for all frequencies up to 30 MHz. The input impedance of the system shall be equivalent to a resistance of not less than 1 Megohm shunted with a capacitance not exceeding 10 pF. The amplitude response of the measurement system shall be dc coupled and have an upper 3 dB bandwidth of at least 50 MHz. The system shall have facilities for external triggering and recording of the oscilloscope trace.

6.19 AF Injection Transformer Characteristics

The audio injection transformer for use in the ACS 01 test, shall be capable of carrying all currents without saturation.

The output impedance of the transformer shall be less than or equal to 0.5 ohms when coupled to the amplifier which supplies the power.

6.20 Frequency Scanning Speeds

When performing emission measurements, consideration shall be given to the rate at which the frequency is scanned with respect to receiver bandwidth.

To avoid amplitude measurement errors, the minimum time, T, to scan the band for a linear frequency scan rate is the frequency span divided by the bandwidth squared.

This equation determines the minimum scan time which will allow the receiver detector to reach the peak value; in practice, a longer scan time will generally be required to allow for data collection and/or the response of analogue X-Y plotters. Consideration must also be given to the prf of the interfering signal being measured.

Scanning speeds for susceptibility tests shall be selected to allow a high probability of intercept (probability of identifying a susceptibility situation) i.e. the output time constant of the malfunction or degradation indicator in the EUT versus frequency scanning speed.

6.21 Plot Charts

Plot charts used to record EUT emissions shall incorporate as a minimum:-

(a) Calibrated frequency graduations.

(b) Calibrated amplitude graduations (at least every 10 dB).

(c) Specification limit or equivalent specification limit.

(d) Receiver bandwidth.

(e) Receiver scan rate.

(f) Detector function and hold time.

(g) Transducer used.

(h) Attenuator settings.

(i) The EUT mode of operation and lead under test as applicable.

(j) Date of test.

(k) Title of EUT.

(l) Test method.

Receiver scan rates and detector peak hold time shall be selected to be compatible with each other, the X-Y plotter and the type of interference being measured. The detector hold time shall be at least 0.3 seconds when using analogue X-Y plotters.

6.22 Susceptibility Criteria

In conducted and radiated susceptibility testing, there must be criteria for an operator to determine malfunction or degradation in the EUT so that either an in-specification or out of specification condition may be ascertained. The criteria for malfunction or degradation shall be specified in the Test Plan.

The threshold of susceptibility is the minimum interference signal level (conducted or radiated) which causes the specified malfunction or degradation.

6.23 Modulation Characteristics

Any analysis of EUT's which contain one or more amplifiers or sensitive circuits which are not communications-electronics receivers will usually reveal that it is likely to be more sensitive to one kind of modulation than another. The modulation most likely to have the greatest effect on the EUT shall be selected (providing it is realistic) and specified in the EMC Test Plan.

As a minimum requirement the following types of modulation shall be applied to both radiated and conducted susceptibility tests unless the test plan details specific alternatives.

20 Hz - 50 kHz	CW
50 kHz - 2 MHz	(a) CW (b) AM, 100% square wave at 1 kHz prf
2 MHz - 30 MHz	(a) CW (b) AM, 100% square wave at 1 kHz prf (c) AM, 100% square wave at 1 - 3 Hz prf
30 MHz - 1 GHz	(a) CW (b) AM, 100% square wave at 1 kHz prf

IN ADDITION FOR RADIATED TESTING ONLY

150 - 225 MHz 580 - 610 MHz 790 MHz - 18 GHz	(a) CW (b) A double modulation consisting of 100% pulse modulation with a prf of 1 ($^+/_-$ 0.1) kHz with a pulse duration of 1 ($^+/_-$ 0.1) us together with a square wave modulation at 100% with a frequency of 0.5 ($^+/_-$ 0.1) Hz. The peak rms field strength shall be a minimum of 5 x CW limit.

The external environment should be considered when selecting the multiplier.

When measuring modulated or unmodulated test signals a peak detector voltmeter calibrated in terms of the rms value of an equivalent sine wave and responding to true peak values shall be used.

6.24 Equipment Under Test's Operating Frequency Selection

Measurements shall be performed with the EUT tuned according to the following rules.

Where the EUT has only one tuneable band (without band switching) or a single range of fixed channels, tests shall be performed with the EUT tuned to frequencies or channels not more than 5 percent removed from the lower and upper tunable frequency limits. If these selected frequencies are of ratio greater than 2:1, tests shall also be performed with the EUT tuned to the centre frequency of the tuneable band or range.

For the EUT with multiple tuning bands or ranges of fixed channels, tests shall be performed with the EUT tuned to frequencies 5 percent removed from the extremes of each band or range.

Where this would involve greater than six tests, the tests shall be performed with the EUT tuned to the centre frequency at each band or range only.

6.25 Transient Generators and Injection Probes

The transient generators required for test method ACS 04 shall provide two types of damped sinusoid transient. Type 1, a variable frequency transient tuneable over the frequency range 2 MHz to 30 MHz, and, Type 2, a fixed frequency transient of 100 kHz. The transients are injected into cable looms using specially designed injection probes.

(i) Type 1 Transients (2 to 30 MHz)

The transient shall be a damped sinusoid capable of being tuned to resonance at any frequency between 2 MHz and 30 MHz. The injection probe shall be an ERA Type 45. The damping of the transient shall be such that the amplitude of the eigth half cycle shall be at least 25 percent, but not greater than 75 percent that of the largest half cycle as shown in Figure 38. This is idealised, in practice due to coupling problems the first half cycle may not be the largest. The damping of the transient waveform shall be verified by injecting into a calibration jig terminated at each end in a load resistance of 50 ohms. The damping of the voltage waveform across the 50 ohm resistor shall comply with the requirements specified above for all transient voltages above 50 volts. The calibration jig specified for Test ACS 02 shall be used for these waveform validation tests.

(ii) Type 2 Transients (100 kHz)

The transient shall be damped sinusoid tuned to resonance at 100 kHz. The injection probe shall be an ERA Type 50. The damping of the transient shall be such that the amplitude of the third half cycle shall be at least 25 percent, but not greater than 50 percent that of the first half cycle as shown in Figure 39. The damping of the transient waveform shall be verified by injecting into a short loop of wire terminated in a load resistance of 5 ohms. The inductance of the cable loop shall not exceed 0.5 uH. The damping of the voltage waveform across the 5 ohm resistor shall comply with the requirements specified above for all transient voltages from 50 volts to 700 volts.

It should be noted that the damping of the transient waveforms is verified by injecting into specified resistive loads. When injecting into cables the damping may vary considerably from the calibration value.

Both types of transient generators shall be capable of injecting the levels of cable currents and cable voltages required by the limits specified for test ACS 04. Control of the point of application of the transients on a.c. power lines with respect to the phase of the a.c. waveform shall be available together with an external trigger and variable transient repetition rate.

Additional information regarding the design details and performance requirements of the generators and injection probes are available in RAE

Technical Memorandum FS(F)550 and design details of the injection probes in RAE Technical Memorandum FS(F)588.

6.26 EMI Antennas

The following electric field antennas shall be used for test method ARE 02 and ARS 02 as applicable.

Frequency Range	System or Method	Test Method ARE 02 Receiving Antennas Orientation	Test Method ARS 02 Transmitting Antennas Orientation
10 kHz - 30 MHz	Parallel plate or long wire transmission line.	N/A	Vertical
10 kHz - 25 MHz	1 metre passive rod antenna with a 600 mm square counterpoise bonded to the test bench.	Vertical	N/A
25 MHz - 200 MHz	EFG 1, 2 or 3	N/A	45 degrees
	Cavitenna	N/A	As manufacturers instructions
	Biconical	45 degrees	45 degrees
200 MHz - 1 GHz	Conical Spiral Antenna	Circularly polarised	
	Dipole	N/A	45 degrees
	Log Periodic	N/A	45 degrees
	Double ridged waveguide horn	N/A	45 degrees
1 GHz - 10 GHz	Waveguide horn (including double ridged)	45 degrees	45 degrees
10 GHz - 18 GHz	Waveguide horn	45 degrees	45 degrees
	Waveguide horn and dish	45 degrees	45 degrees
	Double ridged waveguide horn	45 degrees	45 degrees

Alternative antennas may be used with the approval of the Project Manager or technical authority.

6.27 Production and Measurement of Magnetic Fields

6.27.1 Radiated Emission Testing over the Frequency Range 20 Hz to 50 kHz

A loop consisting of 36 turns, bunch or layer wound, shall be used with dimensions not exceeding 5 mm in length and an internal diameter of 133 mm. The loop shall be wound from stranded wire (7 strands of insulated wire approximately 0.11 mm diameter). See Figure 41. Commercially produced antennas are available for this test.

6.27.2 Radiated Susceptibility Testing over the Frequency Range 20 Hz to 50 MHz

The magnetic field generating loop for Test Method ARS 01 shall be constructed in accordance with Figure 46.

6.28 Production and Measurement of Electric Fields

6.28.1 Radiated susceptibility testing over the frequency range 50 kHz to 25 MHz - design aspects for transmission lines

The parallel plate is a transmission line terminated in its characteristic impedance and used over the frequency range where transverse electromagnetic (TEM) waves only are propagated in the plate; the E component is vertically polarised and the H component horizontally polarised. Its theoretical upper frequency limit is determined by the waveguide cut-off frequency above which other modes exist. In practice the upper frequency limit is lower than this, determined by imperfections in the plate and the coupling between it and the shielded room.

The present standard method of determining the electric field strength produced in the parallel plate is to measure the voltage across the terminating resistor and divide by the plate separation in metres. For example, for the plate separation of 0.457 m an applied voltage of 1 volt will give a field strength between the plates of approximately:

$$\frac{1}{0.457} \times 1 \text{ volt/metre} = 2.19 \text{ volts/metre}$$

Measuring the voltage across the load can lead to errors for the following reasons:

(a) If the voltage is measured using a broadband rf voltmeter, rf breakthrough can lead to errors.

(b) The addition of a voltmeter or emi receiver on the load can disturb the operation of the plate due to multiple earths.

(c) Any standing waves on the plate will give misleading readings.

The preferred method is to measure the E field in the plate by means of a small self-contained E field sensor which will remove these problems and enable improvements to be made to the load termination. However, care must be taken to ensure that the sensor is not affected by fields from the equipment under test. This can be avoided by using care in positioning the sensor in the plate. The sensor should be mounted on a 50 mm insulator of low dielectric constant e.g. expanded polystyrene.

An alternative method is to use a small antenna such as a short dipole to measure the E field in the plate. The screened cable from the antenna to the emi receiver should have ferrite loading around the screen at the point where the cable enters the parallel plate to prevent degradation of the plate's performance.

An alternative method is to pre-calibrate the plate before the test. This involves measuring the forward power to the plate to give the required field as measured by the field sensors.

6.28.1 (cont)
The sensor is replaced by the EUT and the same forward power is supplied to the plate that gave the required field strength with the plate empty.

The parallel plate should be correctly terminated in its characteristic impedance (Zo) where:

$$Zo^2 = \frac{L}{C}$$

L = short circuit inductance of the plate.

C = open circuit capacitance of the plate.

In practice as these parameters are difficult to measure accurately, a time domain reflectometer (TDR) should be used to determine the correct load. The TDR also has the advantage of highlighting any impedance discontinuities in the plate due to construction defects. As the plate's position in the shielded room and its earthing can affect this impedance it should be measured in its permanent location. The plate should be terminated by resistive card for optimum performance. This card is readily available in a variety of lengths and resistances, has minimal reactance and can absorb high power.

A swept VSWR measurement should be made after terminating the plate to determine its performance in the frequency domain. Absorber material can be used to reduce the resonances between the plate and the shielded room. The plate should be earthed to the room at a position causing minimum disturbance to the plate's characteristics. This earth is required for safety reasons in case the equipment under test has any decoupling on ac inputs to chassis and when 10 uF feedthrough capacitors are being used. To match the rf power source to the plate, an impedance matching transformer may be used. This also avoids producing an earth loop between the plate and rf power source.

An outline design of a parallel plate is shown in Figure 6. The required resistive load will be approximately 90 ohm to 115 ohm. This plate should operate to 30 MHz before any significant standing waves occur. Different parallel plate designs may be used providing the test house has ensured they are operating in the TEM mode and have minimal standing waves over the operational frequency range.

The equipment to be tested shall be placed between the plates and bonded to the bottom plate at the same equipment points as would be used in the aircraft. The 10 uF feedthrough capacitors and LISN's shall also be bonded to the bottom plate at the most convenient point depending on equipment layout. It is preferable to ground them near the parallel plate's bonding point to the screened room.

The cables leading to the EUT shall be supported on 50 mm insulated stand-offs as in paragraph 6.8 and shall be arranged to lie centrally along the length of the parallel plate with the EUT at the load end of the plate.

Other similar transmission lines may be used and one example which is suitable for assessing the susceptibility of large equipments is the long wire line installed in the screened enclosure. A typical arrangement is shown in Figure 7 where the em field is developed between the long wire and the ground plane on a test bench. In the operation of the long wire line it is important that the actual field strength should be

6.28.1(cont)

monitored in the location of the EUT using a small portable sensor in order to minimise the errors caused by the shielded enclosure. The resistive load should match the characteristic impedance of the line and a matching network or transformer may be used at the generator end of the line.

In any version of the transmission line disturbance of the field by the EUT should be reduced as far as possible and the overall size of the system under test should not exceed 0.7 times the length, 0.4 times the height, or 0.6 times the width of the parallel plate transmission line.

6.28.2 Radiated susceptibility testing over the frequency range 25 MHz to 18 GHz - field generation

The antennas should be selected from those listed in paragraph 6.26.

Antenna positioning relative to the ground plane and EUT should be as shown in Figures 8, 9 and 10 (top diagram) as far as possible. However, the field strength shall be monitored and it is permitted to adjust the antennas to obtain sufficient field strength. The minimum distance shall not be less than 1 metre.

In the case of horn antennas the dimensions of Figure 10 (top diagram) shall apply with the measurements taken from the centre of the horns outer orifice.

If the beam width of the antenna used is too narrow to allow complete coverage of the EUT then further scans shall be made with the antenna repositioned each time.

At frequencies above 1 GHz discontinuities in the screening of the EUT shall be presented to the transmitting antenna directly, i.e. turn the EUT so that numerical displays, CRT screens, LRU connectors etc are normal to the main beam of energy from the transmitter antenna.

6.28.3 Radiated susceptibility testing over the frequency range 50 kHz to 18 GHz - field monitoring

In the past, large errors have occurred because the electric fields have been monitored on the opposite side of the transmitting antenna to the EUT for omni-directional antennas and by 'bore sighting' for directional antennas. The assumptions made when using these methods are not valid due to the complex field distribution in a screened room. The best solution is to use an anechoic chamber. However, at the present time these are not readily available at test houses. Therefore, to minimise the error, the field strength shall be monitored at the EUT. Ideally the field sensor should be placed close to the most susceptible part of the EUT; however in most cases the location cannot be established with certainty. One method which can be used to locate and identify areas of low immunity on the EUT is to energise a small sensor which is then passed over the EUT. The sensor shall be energised by signals at frequencies selected as being likely to cause disturbance to the EUT. This procedure is limited in that the areas of low immunity may vary considerably with frequency and it would be difficult to make an exhaustive survey. However, at low radio frequencies transfer of interfering signals is likely to be dominated by cable coupling, whereas at higher frequencies and in the microwave region conduction via cables is very poor so that interfering signals are only likely to impinge on circuit boards via discontinuities in the screening of equipment cases, i.e. numerical displays, CRT screens, meters, waterproof gaskets or terminal housings etc. In general, placing the field monitor near the equipment case close to known discontinuities in the screening or near to cable entries will be closest to the area of maximum susceptibility.

If by use of anechoic lining the variation of the field over the area to be occupied by the EUT is less than $^{+}/_{-}$ 3 dB then pre-calibration of the ground plane before the EUT is in situ is the preferred method.

The field monitoring equipment should have a dimensionally small sensor and ideally be self-contained using a fibre optic link to transfer the read-out away from the EUT. When modulated fields are being measured some sensor characteristics will require correction factors in order that the peak field strength can be obtained.

Small monopole low frequency E field sensors must be positioned relative to the ground plane according to the manufacturers instructions in order that their calibrations are valid; in addition some EUT will produce locally high strength low frequency fields so that care must be taken to establish the validity of the field sensor readings.

Small field sensors or antennas shall be used for field monitoring as follows:-

Frequency range of test	Field sensor/antennas
50 kHz to 200 MHz	Instruments for Industry EFS-1 (see note) or EFS-2 with fibre optic link. Aeritalia SB08
200 MHz to 400 MHz	Monoconical RAE design as shown in Figures 11 to 14. Aeritalia SB08
400 MHz to 1 GHz	LPA70 log periodic Aeritalia SB08
1 GHz to 10 GHz	Double Ridge Waveguide Horn EMCO RGA50
2 GHz to 18 GHz	Double Ridge Waveguide Horn EMCO RGA100

Note: When using a modulated signal the reading on the EFS-1 requires correction factors to be applied.

Other small sensors/antennas may be used with permission of the EMC Control Board.

Above 1 GHz, as the wavelength is short, the field shall be monitored as close to the centre of the EUT as practicable using a small directional antenna. Suitable rf absorbing material shall be placed behind the EUT to minimise reflections.

6.28.4 Radiated emission testing over the frequency range 50 kHz to 18 GHz - *antenna arrangement*

The antennas shall be selected from those listed in paragraph 6.27.

Antenna positioning relative to the ground plane and the EUT shall be as shown in Figures 8 and 10.

In the case of horn antennas the dimensions of Figure 10 (top diagram) shall apply with the measurements taken from the centre of the horns outer orifice.

The 1 metre passive rod antenna counterpoise shall be bonded to the ground plane by a solid metal sheet having the same width as the counterpoise (0.6m).

6.29 SAFETY

Care must be taken to ensure that personnel are not subjected to hazardous rf fields during both conducted and radiated susceptibility testing.

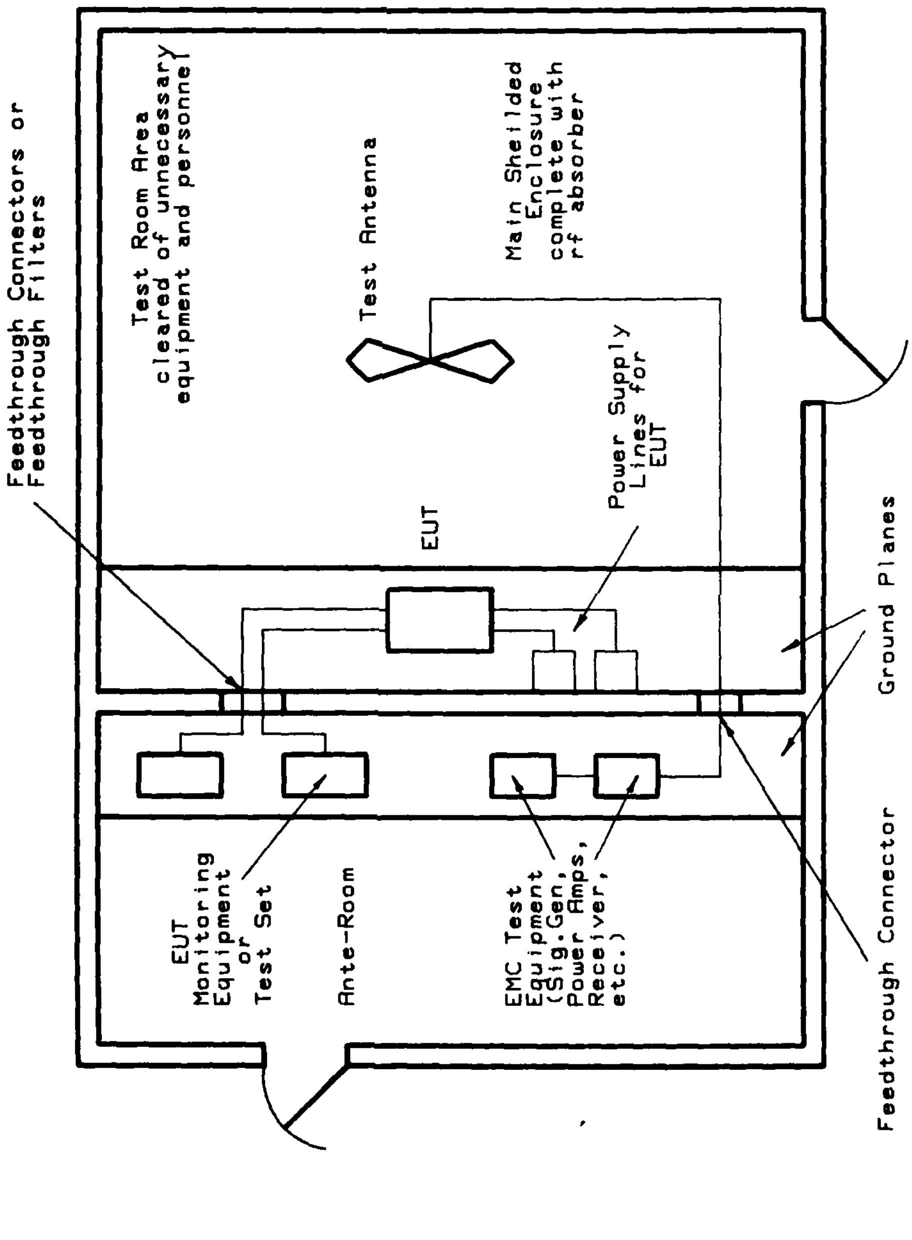
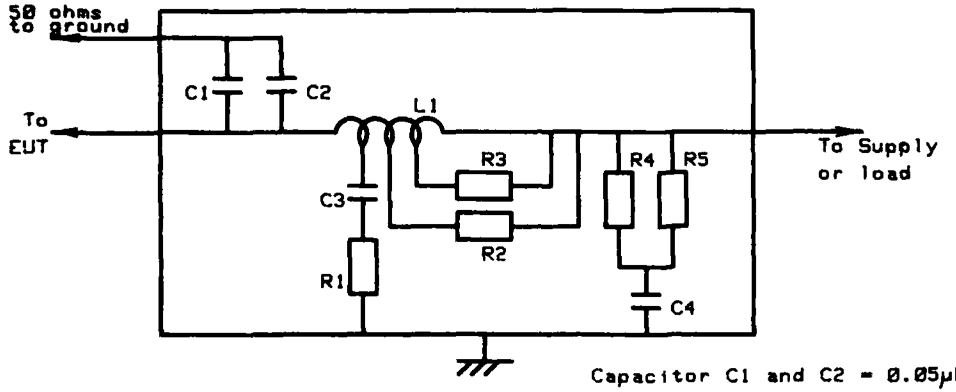


Figure 1 : Suggested Layout for Shielded Room Complex



Capacitor C1 and C2 = 0.05μF
Capacitor C3 = 33pF
Capacitor C4 = 0.25μF
Resistor R1, R2 and R3 = 100 ohms
Resistor R4 and R5 = 10 ohms
Details for Inductor L1 in above circuit
Tappings at 25%, 50% and 75%
All resistors are 2W rating

DETAILS OF L1.

Current Rating (A)	Inductance (uH)	Inside Diameter (mm)	Length (mm)	Number of Turns	Conductor Cross Section (mm)
10	5	25.4	32	20	1.6 dia.
100	5	50	115	18	6 dia.
500	5	90	178	11	12.5 sq.

Figure 2 : Details of Line Impedance Stabilisation Network

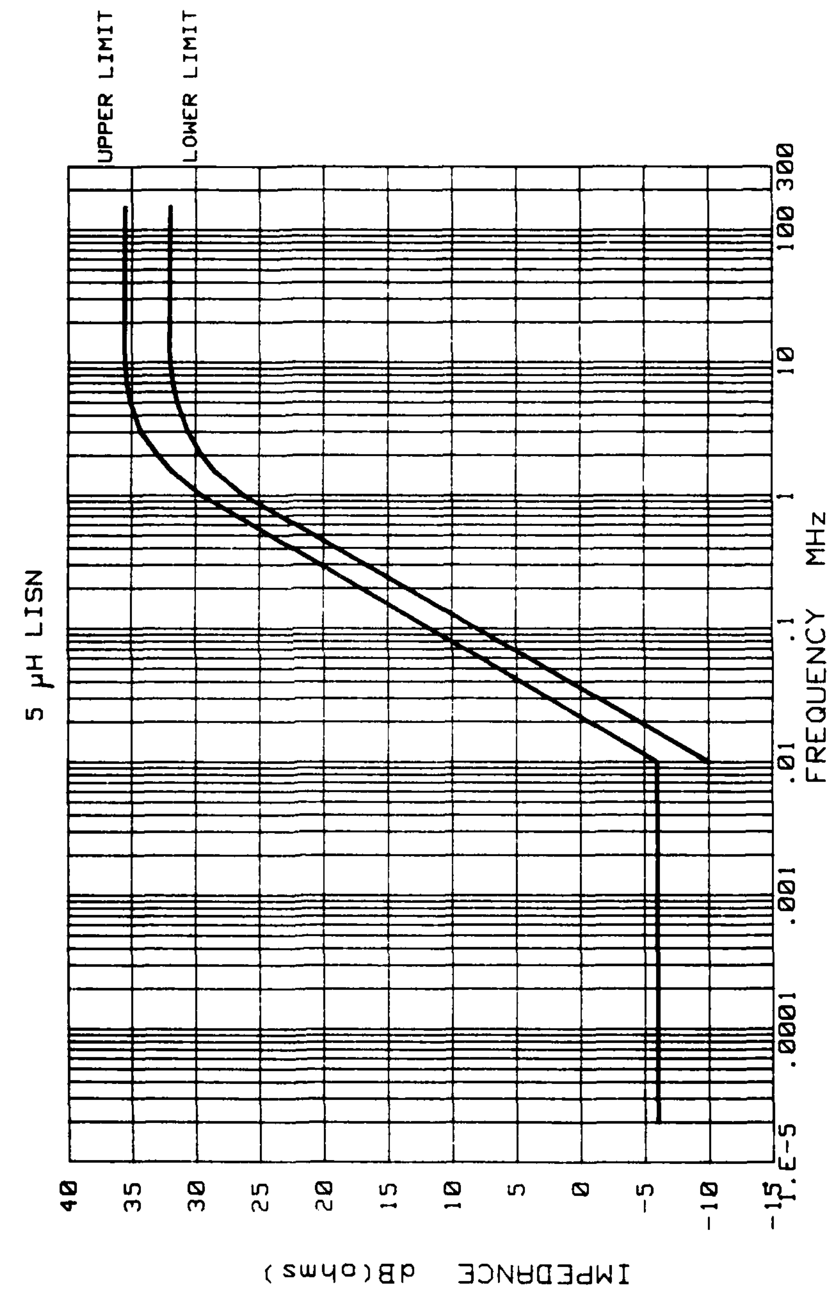


Figure 3 : Impedance Characteristics of the Line Impedance Stabilisation Network

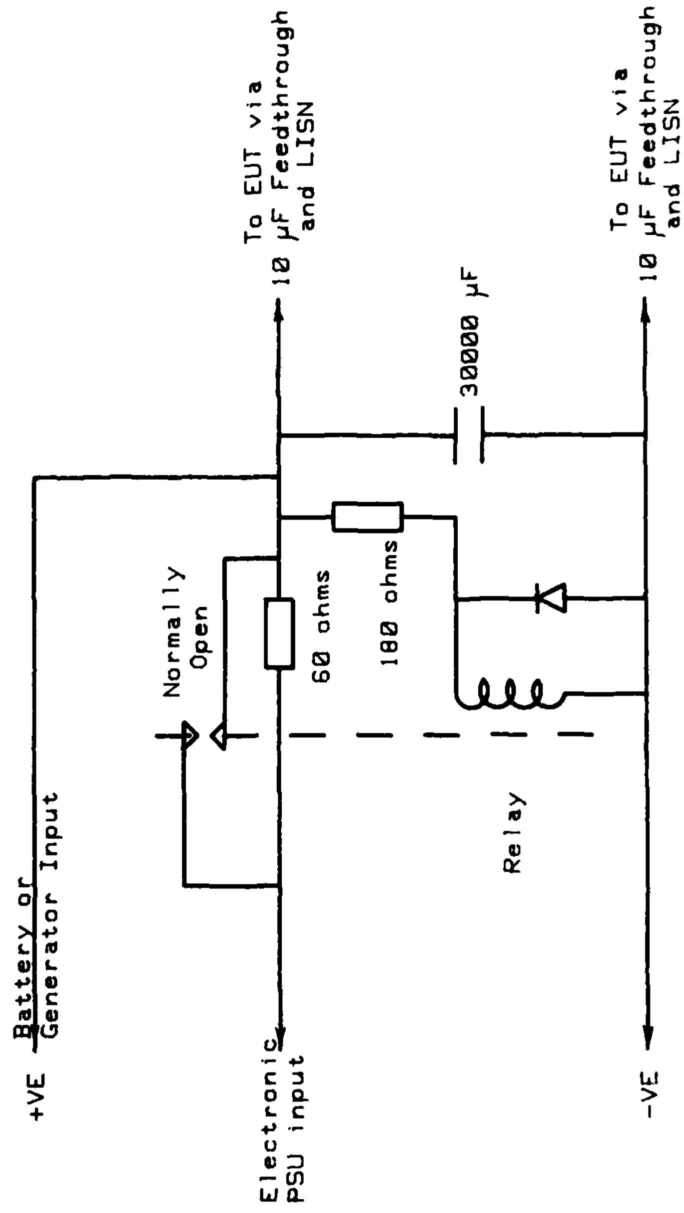


Figure 4 : Modification to DC Supplies to Limit Surge Current

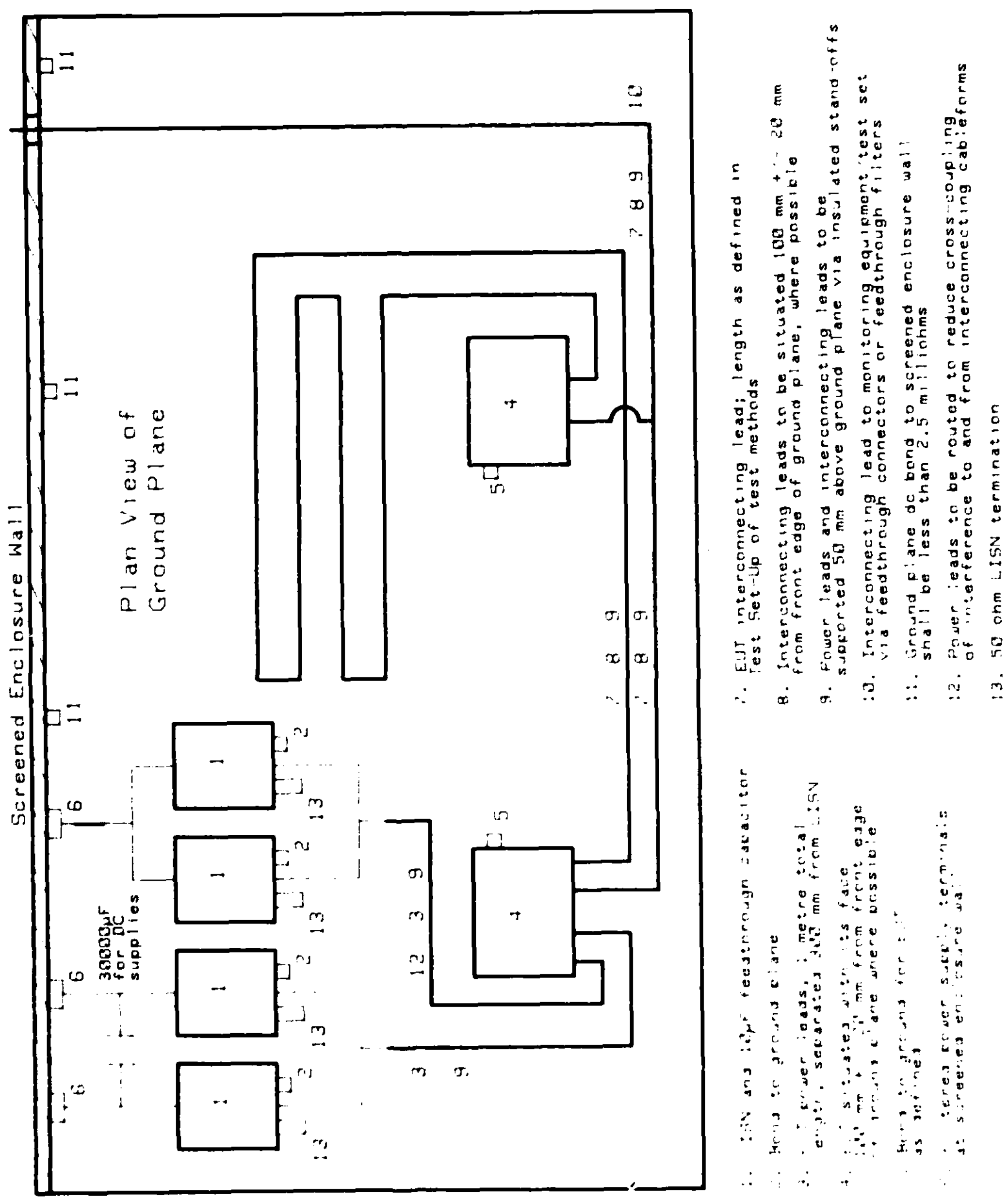


Figure 5 : Arrangement for Long Interconnecting Leads

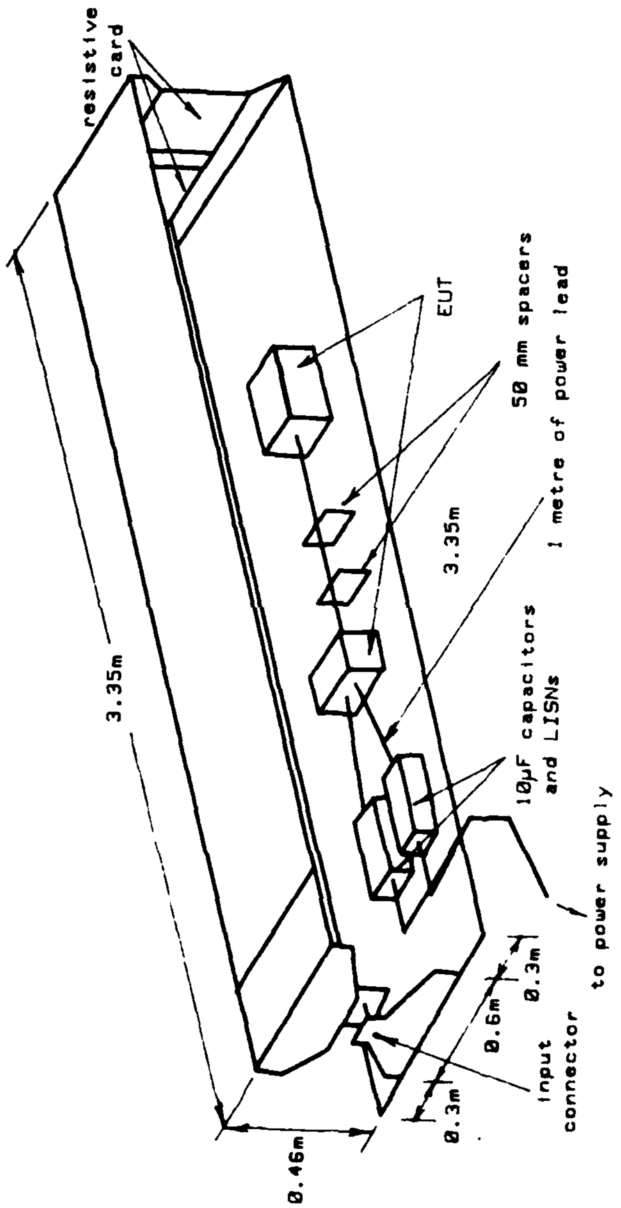


Figure 6 : Typical Parallel Plate for Susceptibility Testing

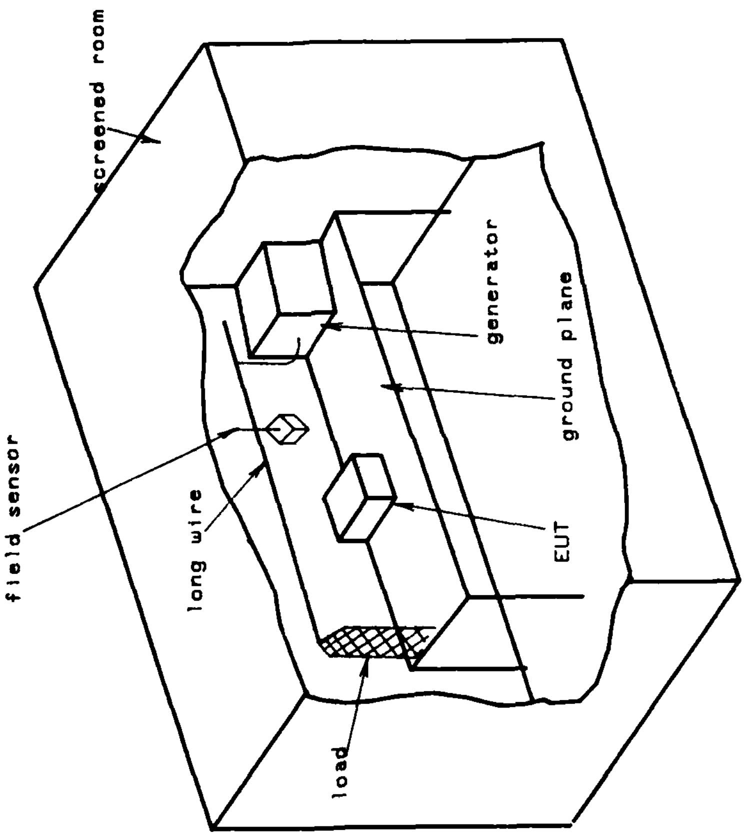


Figure 7 : Test Layout for Radiated Susceptibility Tests using a Long Wire Antenna

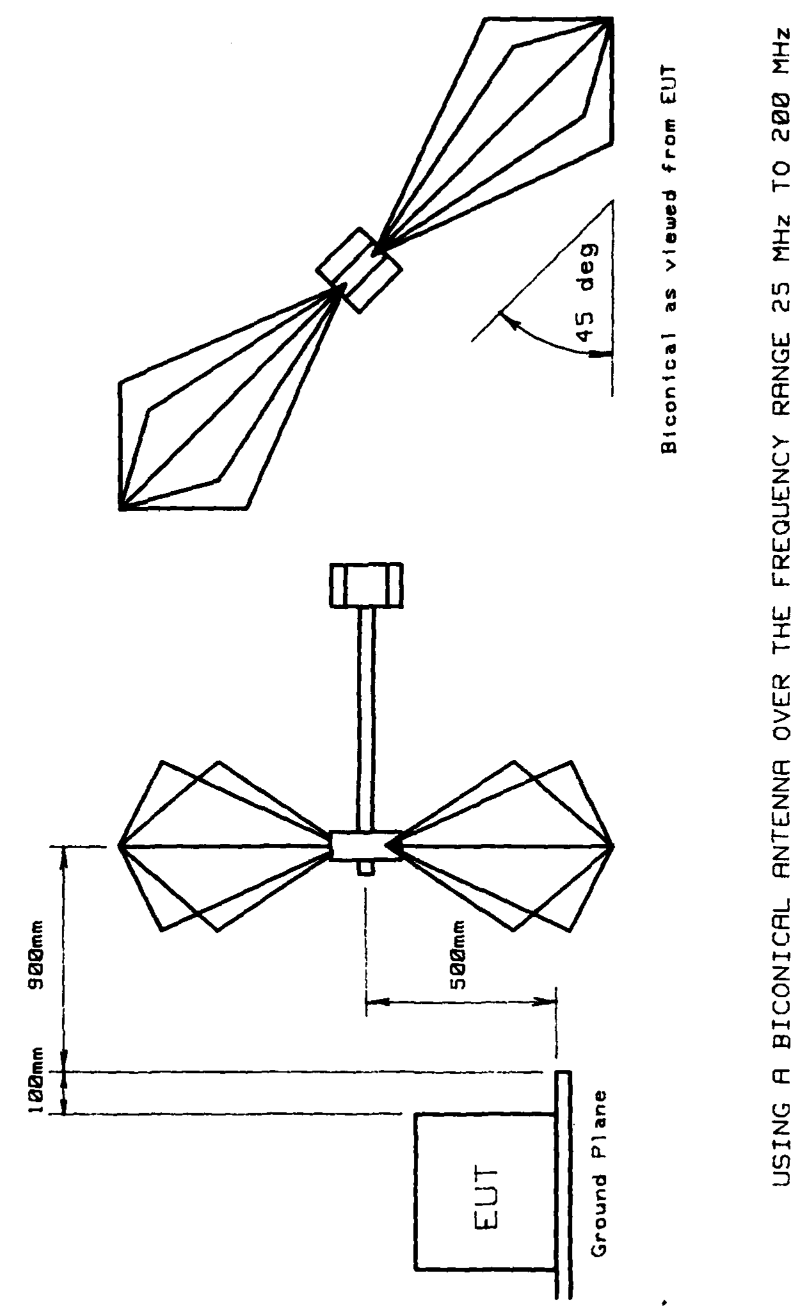


Figure 8 : Typical Arrangement for Radiated Testing Showing Antenna Position

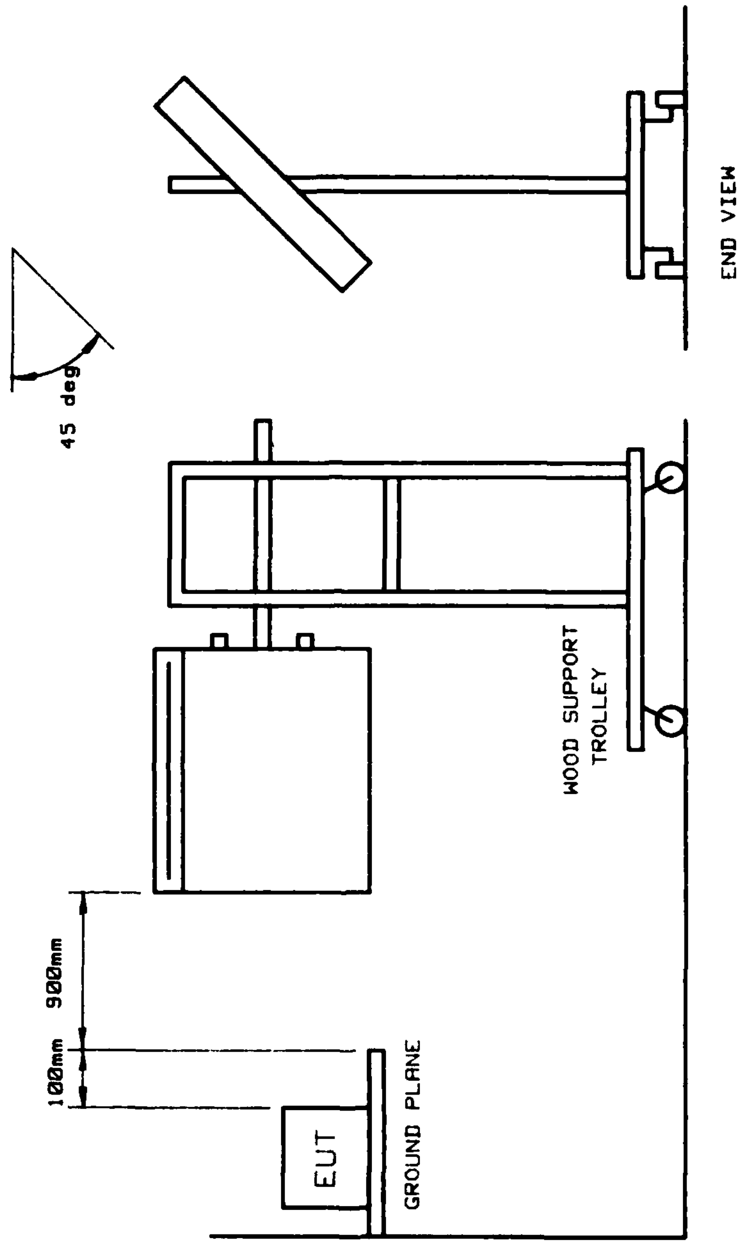


Figure 9 : Typical Arrangement for Radiated Susceptibility Testing using an EFG1, 2 or 3 Antenna

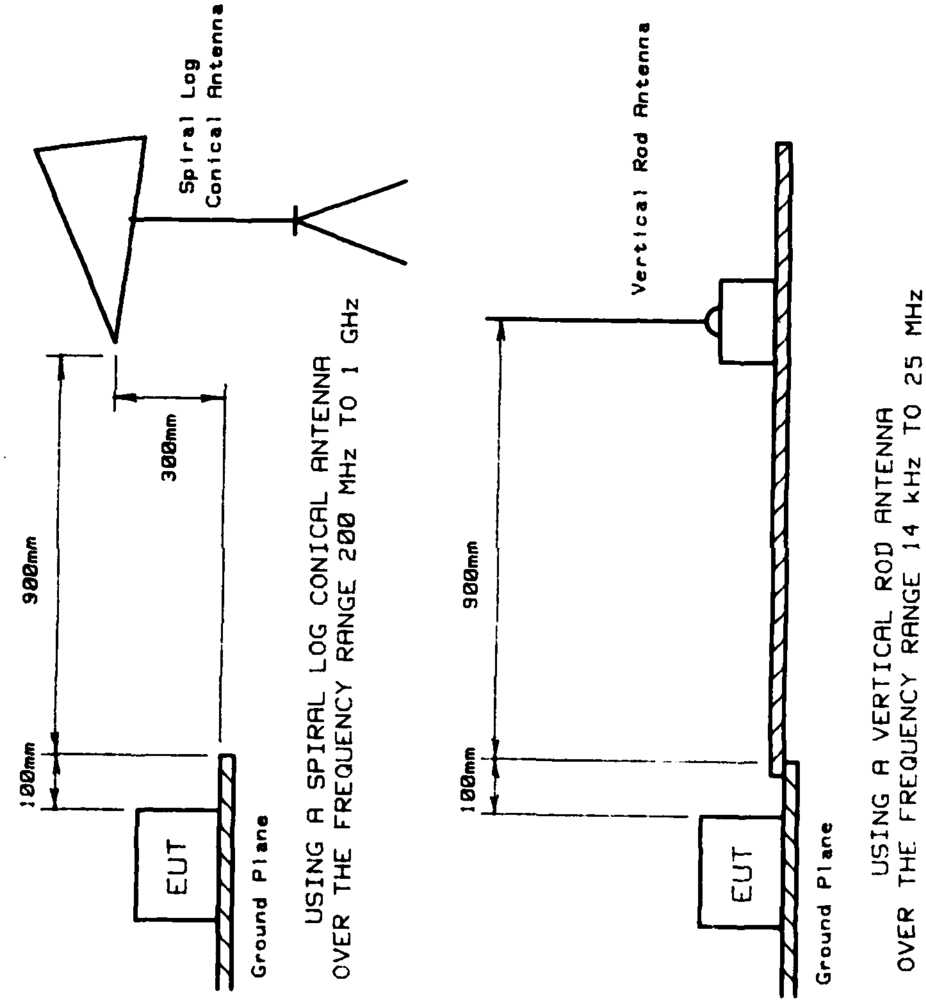


Figure 10 : Typical Arrangement for Radiated Testing Showing Antenna Position

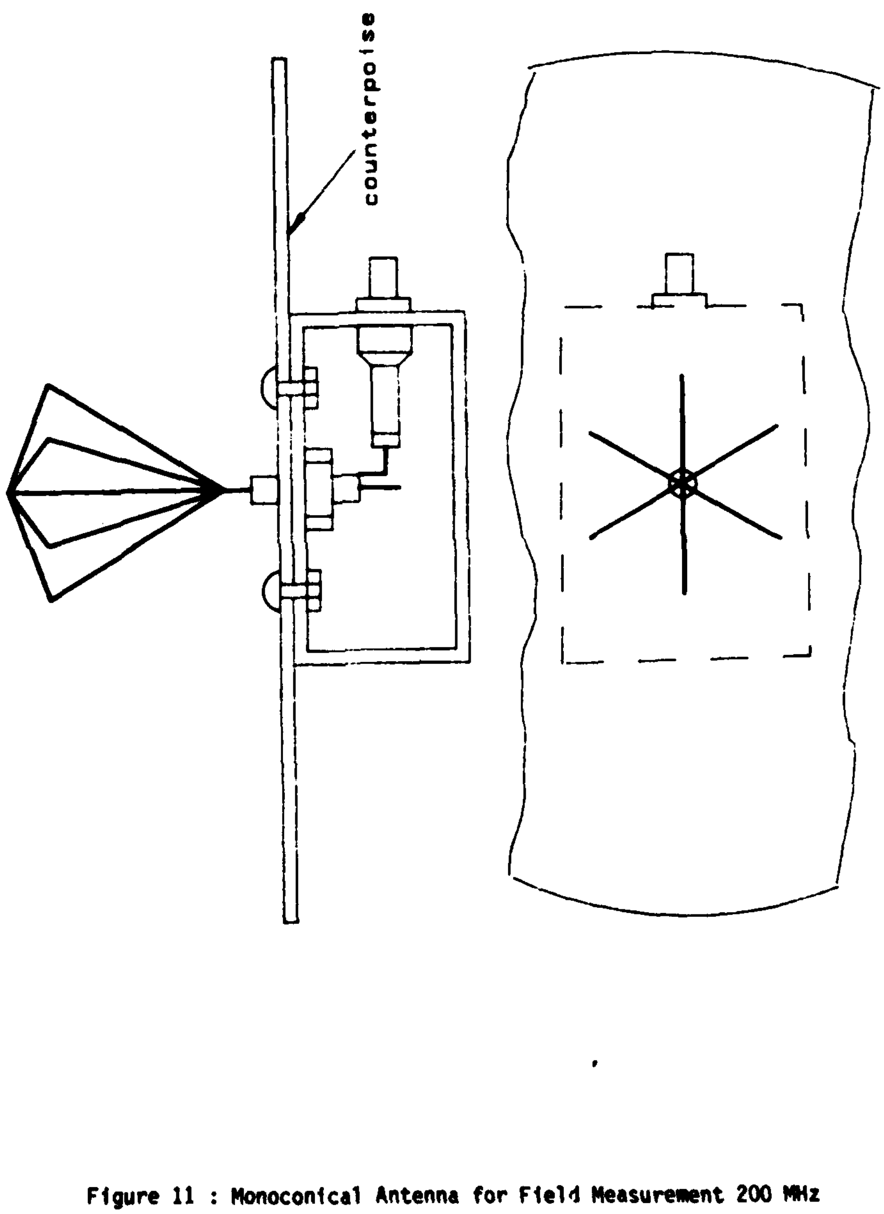
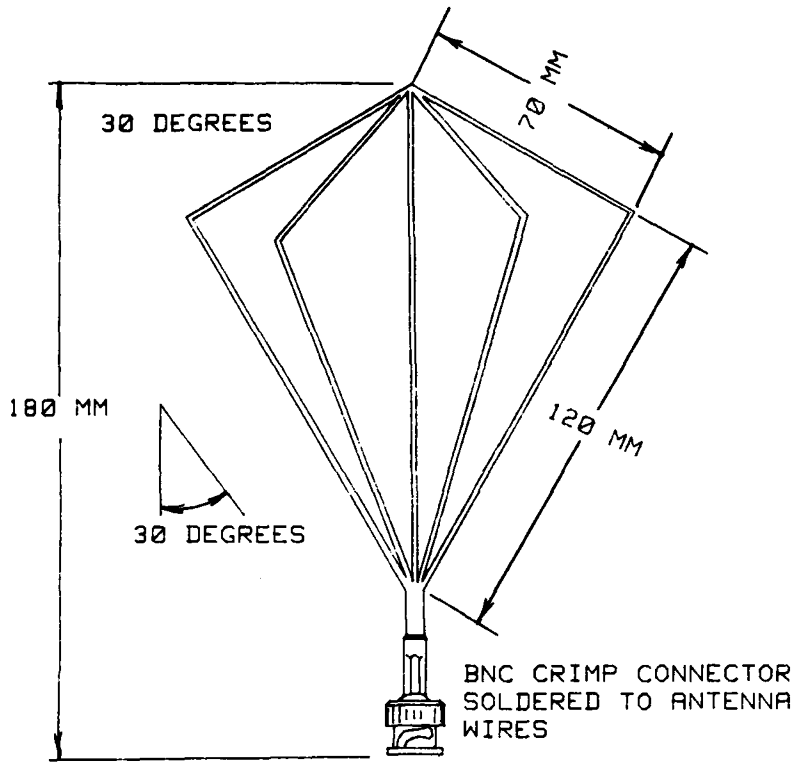


Figure 11 : Monoconical Antenna for Field Measurement 200 MHz to 400 MHz; General Assembly, Elevation and Plan



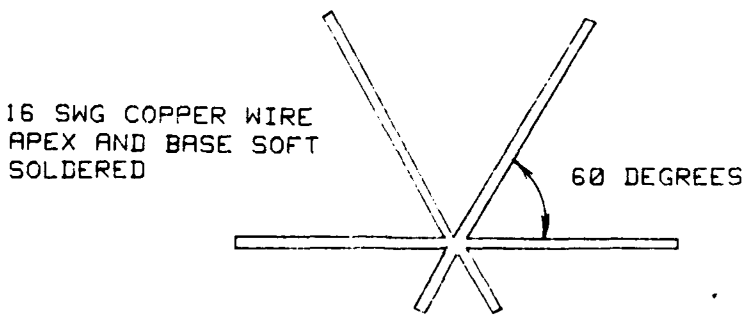


Figure 12 : Monoconical Antenna; Detail of Cone Construction

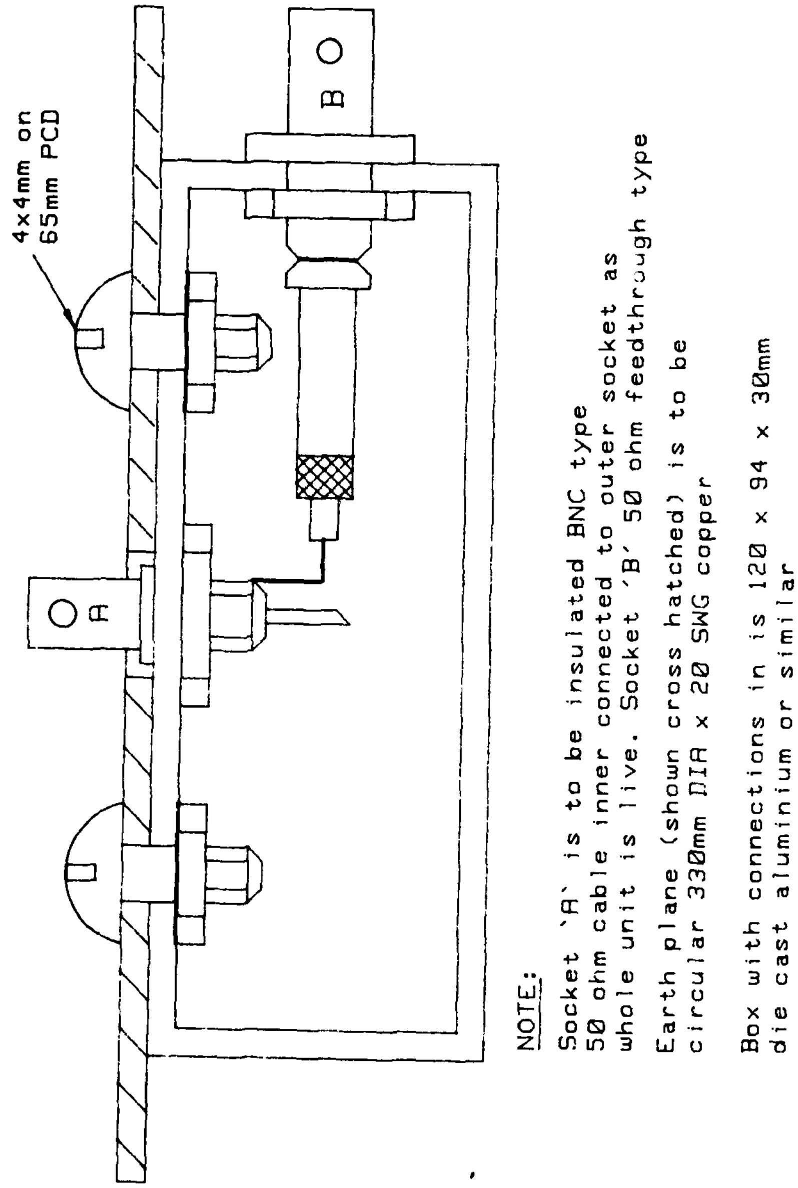
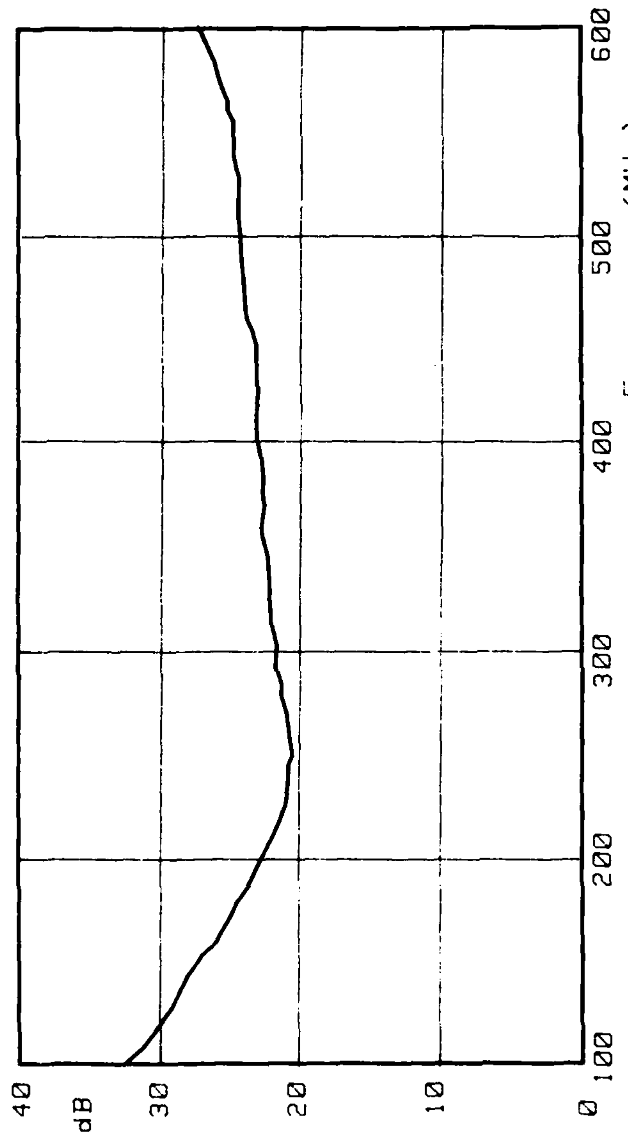


Figure 13 : Monoconical Antenna; Detail of Base



NOTE:

Typical correction factor in dB to be added to voltage measured in 50 ohm system to obtain field strength in volts/metre. These values obtained in accordance with the standard calibration method using two identical antennas.

Figure 14 : Monoconical Antenna; Typical Calibration Curve

SECTION 7.1

ACE 01 CONDUCTED EMISSION; POWER LEADS 20 Hz to 150 MHz

1 Purpose

The purpose of this test is to ensure that the conducted emissions on all power lines to the EUT are controlled to the appropriate limits in order to provide adequate protection of radio reception and to minimise disturbance to any sensitive electronic equipment. Switching devices which operate infrequently in flight may be exempt from this test.

2 Applicability

All a.c. and d.c. power input and output leads of the EUT which connect externally or interface with other equipment not part of the EUT are subject to this test. This includes safety earth and power return or neutral lines, which are connected externally to the system common ground at a distance of greater than 150 mm from the EUT.

3 Test Layout

Section 6 should be studied before commencement of the test.

Figure 15 shows a typical equipment layout for this test. All power lines to be tested shall be connected to their leads on supplies via a line impedance stabilising network (LISN). The measurement port of all LISN's shall be terminated in 50 ohms.

4 Test Method

The current flowing in the line under test shall be measured using a current probe placed 50 mm from the LISN over the frequency range 20 Hz to 150 MHz. More than one current probe will be necessary to cover the frequency band. The measurement bandwidth shall be as defined in section 6.14.

The peak detector on the measuring receiver shall be used for all measurements with sufficient hold time to enable the maximum value of the signal to be recorded.

The results shall be plotted using swept techniques; measurements at spot frequencies only are not allowed. If, however, the interference is caused by a switching operation occurring less than once every 15 seconds the interference shall be measured at enough frequencies to describe the maximumlevel using manual techniques.

5 Test Limits

The measured interference shall not exceed the limits specified in Figure 16; primary power line frequencies being exempt from this requirement.

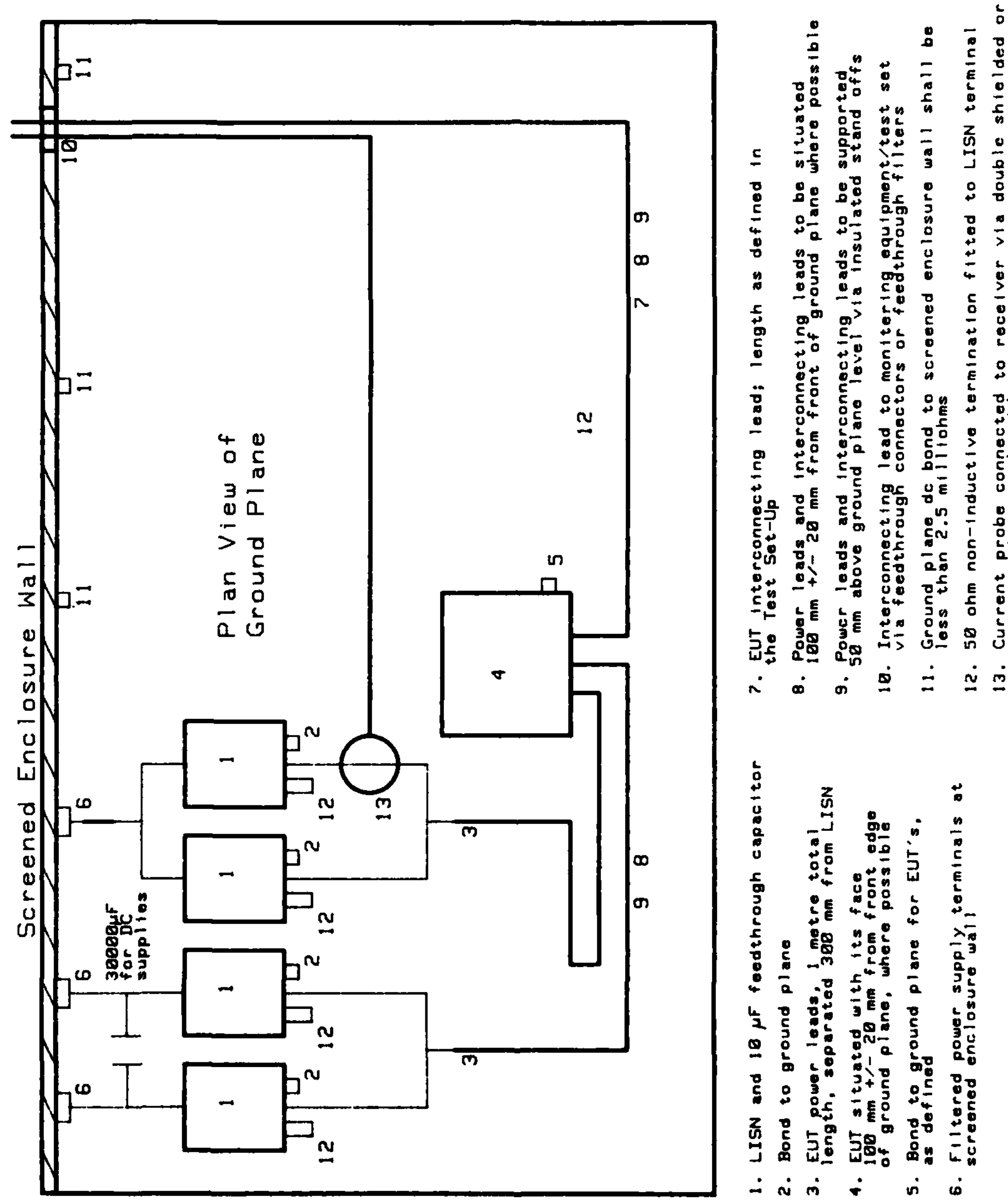


Figure 15 : Typical Test Configuration for Test Method ACE 01

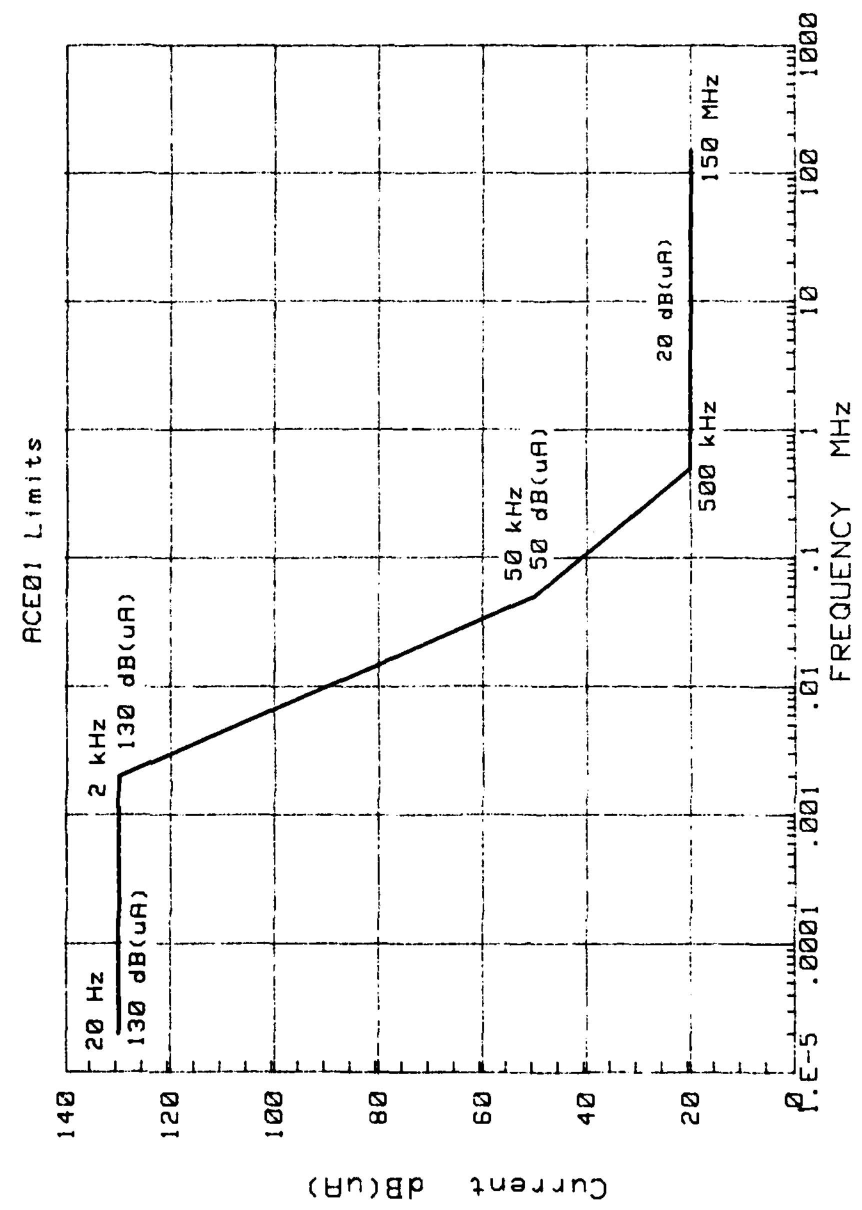


Figure 16 : Limit for Test Method ACE 01; Power Leads, 20 Hz to 150 MHz

SECTION 7.2

ACE 02 CONDUCTED EMISSION, CONTROL AND SIGNAL LEADS 20 Hz to 150 MHz

1 Purpose

The purpose of this test is to ensure that the conducted emissions on all control and signal lines to and from the equipment under test are controlled to the appropriate limits, in order to provide adequate protection of radio reception and to minimise disturbance to any sensitive electronic equipment.

2 Applicability

This is applicable to all control and signal looms.

Power leads which are derived from other equipments in the system under test and not directly from aircraft power supplies are also subject to this test method.

3 Test Layout

Section 6 should be studied before commencement of the test. Figure 17 shows the layout for the test.

4 Test method

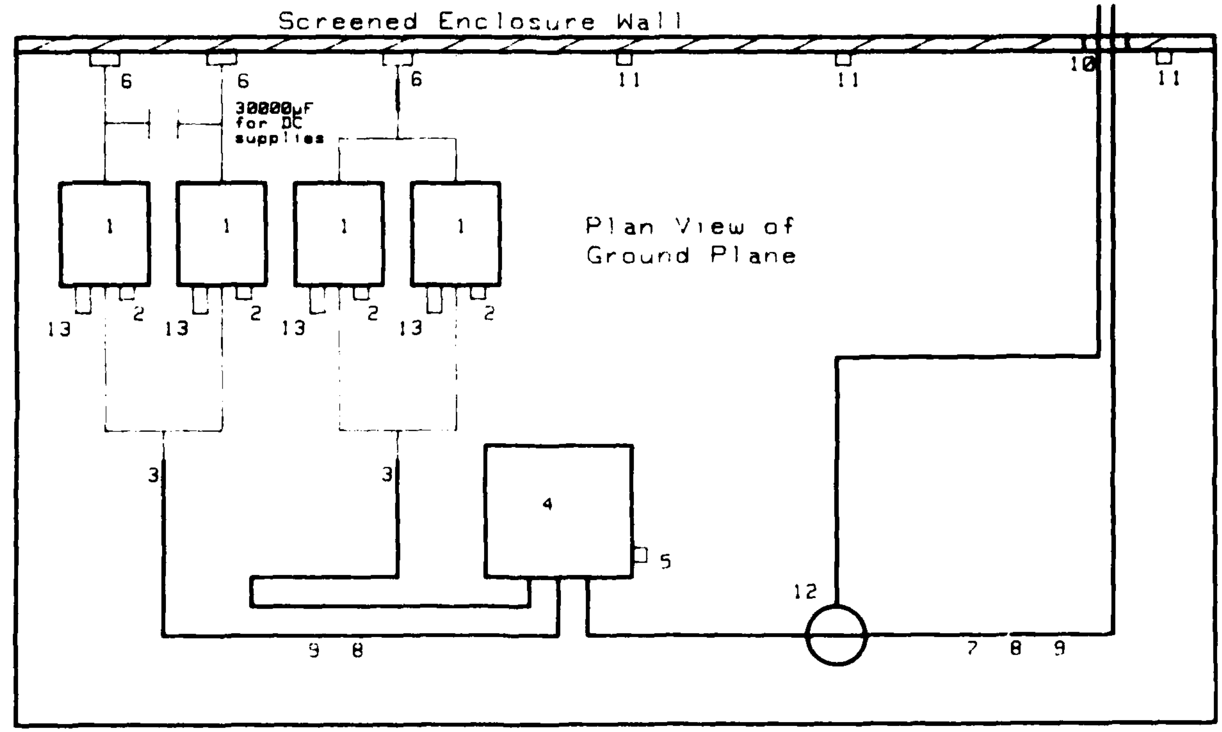
The current probe shall be fitted around the group of leads to be measured at a point within 50 mm of the equipment under test's connector or as close as is practical. This point shall be recorded. Where there are two EUTs linked by a cableform, the current probe shall be positioned at 50 mm from each EUT's connector, in turn. If the lead is less than 0.5 m then the probe shall be placed in the centre of the lead only.

The results shall be plotted using swept techniques; measurements at spot frequencies only are not allowed. If, however, the interference is caused by a switching operation less than once every 15 seconds the interference shall be measured at enough frequencies to describe the maximum level using manual techniques.

The receiver bandwidth shall be selected in accordance with paragraph 6.14.

5 Test Limits

The measured emissions shall not exceed the limits shown in Figure 18.



1. LISN and 10μF feedthrough capacitor
2. Bond to ground plane
3. EUT power leads, 1 metre total length, separated 300 mm from LISN
4. EUT situated with its face 100 mm +/- 20 mm from front edge of ground plane where possible
5. Bond to ground plane for EUT's, as defined
6. Filtered power supply terminals at screened enclosure wall
7. EUT interconnecting lead; length as defined in the Test Set Up
8. Power and Interconnecting leads to be situated 100 mm +/- 20 mm from front edge of ground plane, where possible
9. Power leads and interconnecting leads to be supported 50 mm above ground plane level via insulated stand offs
10. Interconnecting lead to monitoring equipment test set via feedthrough connectors or feedthrough filters
11. Ground plane dc bond to screened enclosure wall shall be less than 2.5 milliohms
12. Current probe connected to receiver via double shielded or semi rigid coaxial cable
13. 50 ohm LISN termination

Figure 17 : Typical Test Configuration for Test Method ACE 02

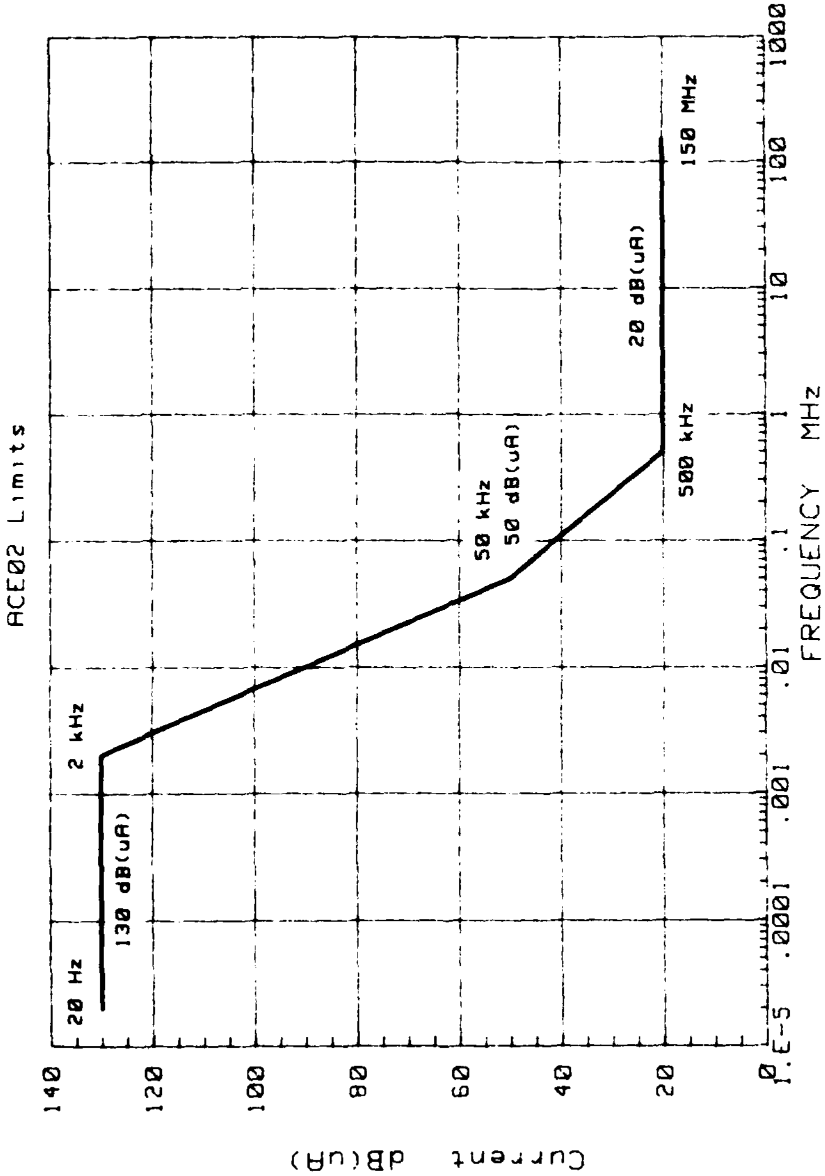


Figure 18 : Limit for Test Method ACE 02; Control and Signal Leads, 20 Hz to 150 MHz

SECTION 7.3

ACE 03 CONDUCTED EMISSION, POWER LEADS, EXPORTED TRANSIENTS

1 Purpose

The purpose of this test is to measure the amplitude and duration of transients appearing on aircraft power leads caused by the normal operation of the EUT and also as a result of switching on and off the power supply to the EUT. These transient emissions may couple via conduction and radiation from the power leads to other potentially susceptible equipments in the actual aircraft installation.

2 Applicability

AC and DC power cables which interface with aircraft power supplies are subject to this test method.

3 Test Layout

Section 6 should be studied before commencement of this test, particularly Section 6.18 which defines the oscilloscope and oscilloscope probe parameters. Figure 19 shows a typical test layout for this test method.

4 Test Method

For all EUT's, a switch or contactor of the type normally intended to control the supply to the EUT in the aircraft shall be connected into the power leads as shown in Figures 20 and 21 for dc and ac lines respectively. If the contactor type is not known then a switch shall be used which complies with the requirements of BS G132. If the power lead lengths are not known then a nominal lead length of 1 metre shall be used. The contactor shall be inserted at the LISN end of the leads. Oscilloscope probe connections shall be made to the power lines at a distance of 50 mm from the EUT connector and also within 50 mm of the LISN's. For measurements at the LISN for ac supplies, filtering of the power supply frequency may be required to aid measurement of the transient. The test plan should give details of extra filtering requirements.

The supply to the EUT shall be switched on and off by means of both, the EUT power switch (if possible), and also the contactor for at least 20 switching operations each. The EUT shall also be operated over its normal sequence and over its full range of functions to obtain the maximum values of transient voltage. The maximum values shall be recorded both at the EUT and LISN for contactor switching operations and at the LISN only for functional switching of the EUT. Some typical oscillograms shall be included in the test report.

The differential transient voltage appearing between the various power lines shall be measured as follows:-

(i) For d.c. lines the transient voltage shall be measured between the positive line and zero volt return line, between the positive line and the ground plane and also between the zero volt return line and the ground plane.

(ii) For single phase a.c. lines the transient voltage shall be measured between the phase line and the neutral line, between the phase line and the ground plane and also between the neutral line and the ground plane.

(iii) For 3 phase a.c. lines the transient voltage shall be measured between each of the phase lines, between each phase line to the ground plane, between each phase line to the neutral line and also between the neutral line and the ground plane.

5 Test Limits

The following limits are shown for 400 Hz and 28 V d.c. systems and are referenced to the supply waveform. It should be noted that different limits may apply for systems operating at other power line frequencies or voltages, in these cases the project technical authority may adjust the limits accordingly.

For measurements at the EUT:-

The maximum voltage excursion of the superimposed exported transient relative to the supply voltage waveform shall not exceed:-

+/- 300 V peak for 200 V L-L or 115 V L-N a.c. equipment
+/-150 V peak for 28 V d.c. equipment

The period for which the voltage excursion of the transient exceeds:-

+/-200 V peak for 200 V L-L or 115 V L-N a.c. equipment
+/-100 V peak for 28 V d.c. equipment

shall not exceed 10 usecs.

The period for which the voltage excursion of the transient exceeds:-

+/-160 V peak for 200 V L-L a.c. equipment
+/- 95 V peak for 115 V L-N a.c. equipment
+/- 80 V peak for 28 V d.c. equipment

shall not exceed 5 msecs.

For measurements at the LISN:-

The maximum superimposed voltage excursion of the exported transient relative to the supply voltage waveform shall not exceed:-

+/-160 V peak for 200 V L-L a.c. equipment
+/- 90 V peak for 115 V L-N a.c equipment
+/- 30 V peak for 28 V d.c. equipment.

These latter limits for measurements at the LISN should be tailored for individual project requirements to take into account the aircraft primary power supply characteristics.

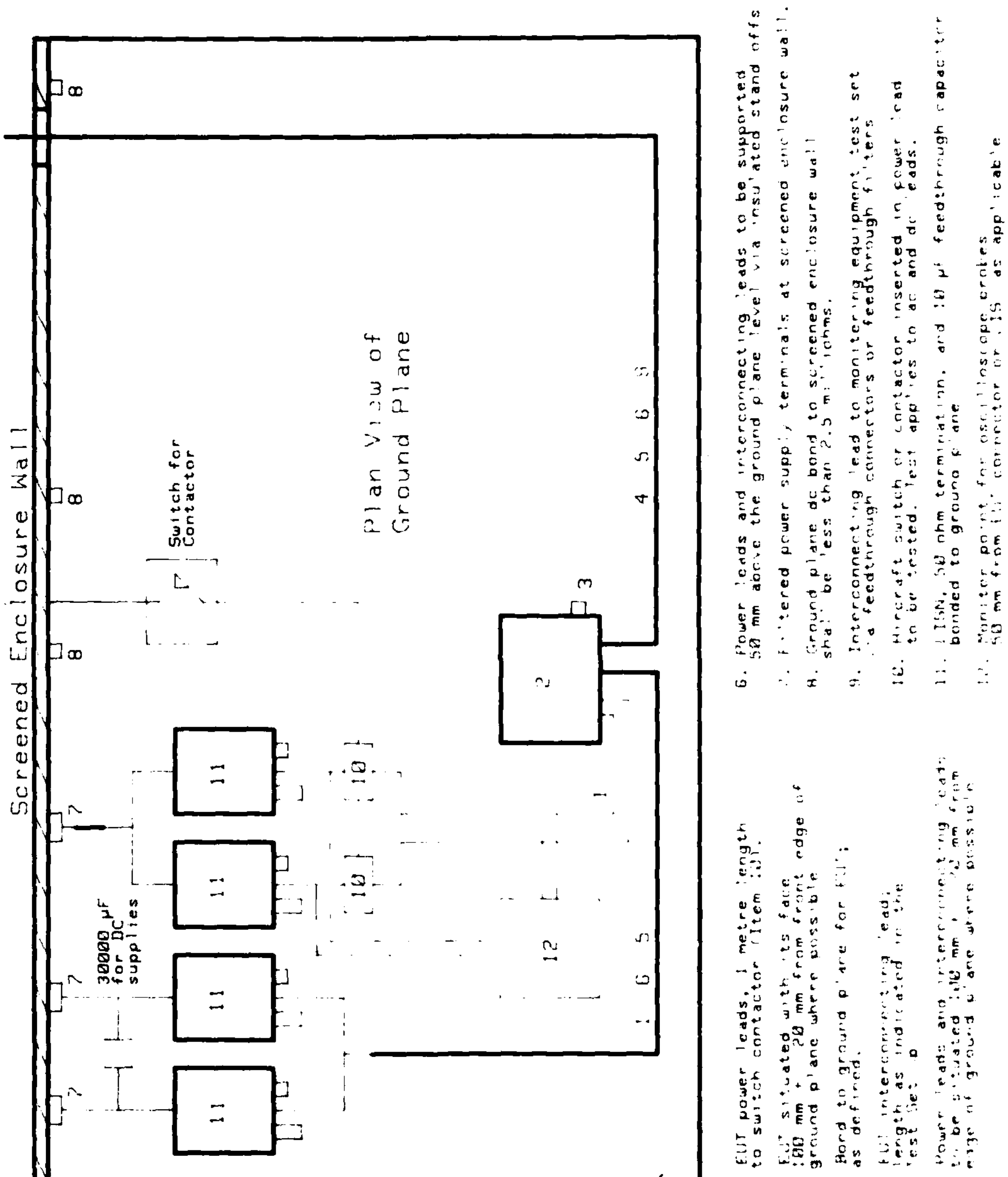


Figure 19 : Typical Test Configuration for Test Method ACE 03; Exported Transients.

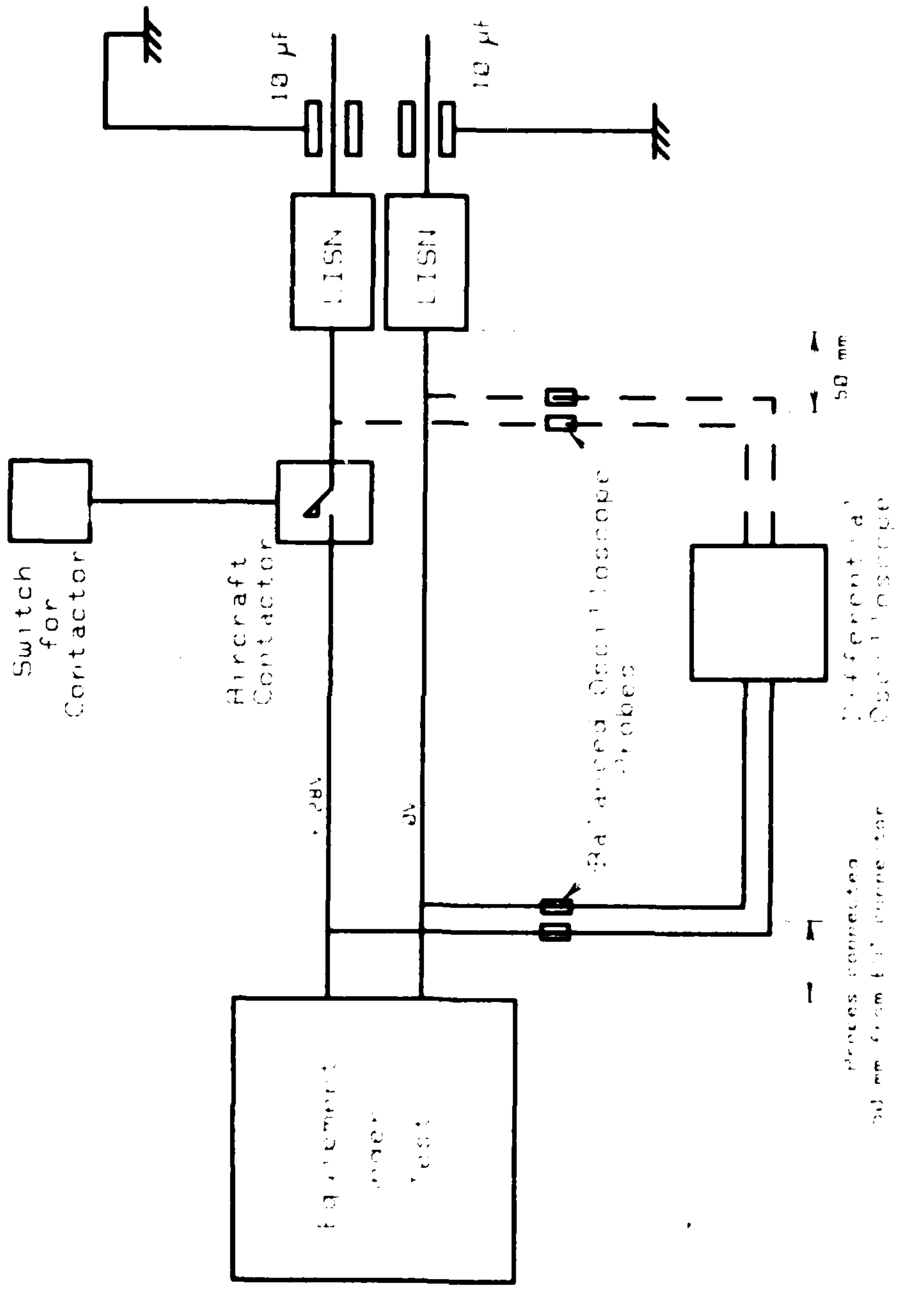


Figure 20 : ACE 03 Test Configuration, DC Supply Leads

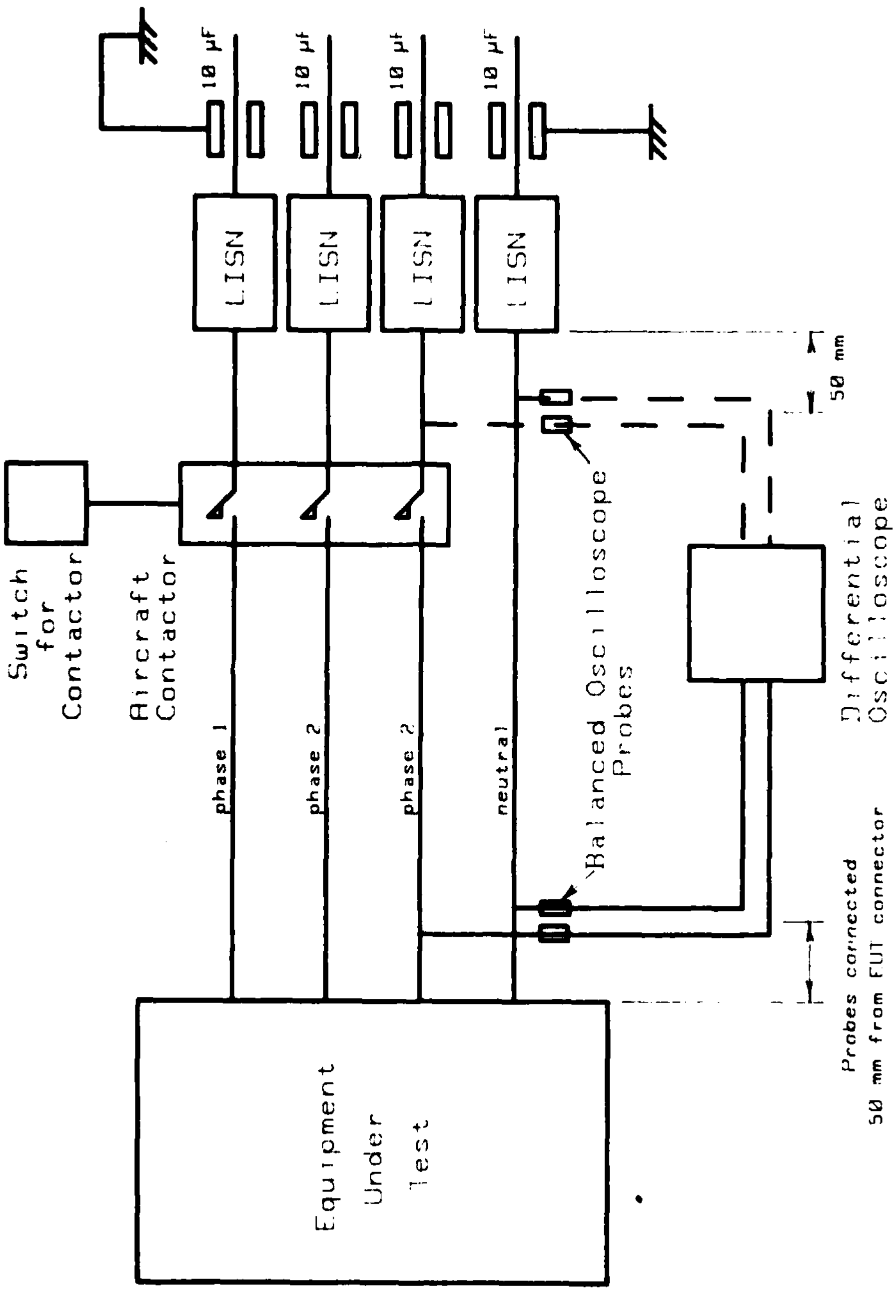


Figure 21 : ACE 03 Test Configuration, AC Supply Leads

SECTION 7.4

ACS 01 CONDUCTED SUSCEPTIBILITY, POWER LEADS, 20 Hz to 50 kHz

1 Purpose

The purpose of this test is to confirm that AF signals of specified levels injected on the power lead of the EUT will not cause degradation of performance or malfunction. Thus the objective is to assure that these signal levels are not likely to result in a conducted EMI problem via power line coupling media.

2 Applicability

AC and DC input leads which interface with aircraft power supplies are subject to this test method.

3 Test Layout

Section 6 should be studied before commencement of the test. Figure 22 shows the layout for the test.

The power leads shall be arranged such that they are segregated from interconnecting cableforms and from each other to prevent cross-coupling of interference.

4 Test Method

The equipment shall be connected as shown in Figure 23.

The signal amplitude shall be set to the specified level at 50 kHz. The frequency will then be slowly swept downwards to 20 Hz whilst adjusting the amplitude to the levels specified. During this sweep the EUT shall be monitored for malfunction as described in Test Plan.

At the frequencies where the EUT is susceptible the signal amplitude shall be reduced until a threshold of susceptibility is determined. Check for hysteresis in signal amplitude by decreasing through the susceptibility threshold and then increasing through the threshold. The lesser of the two shall be recorded.

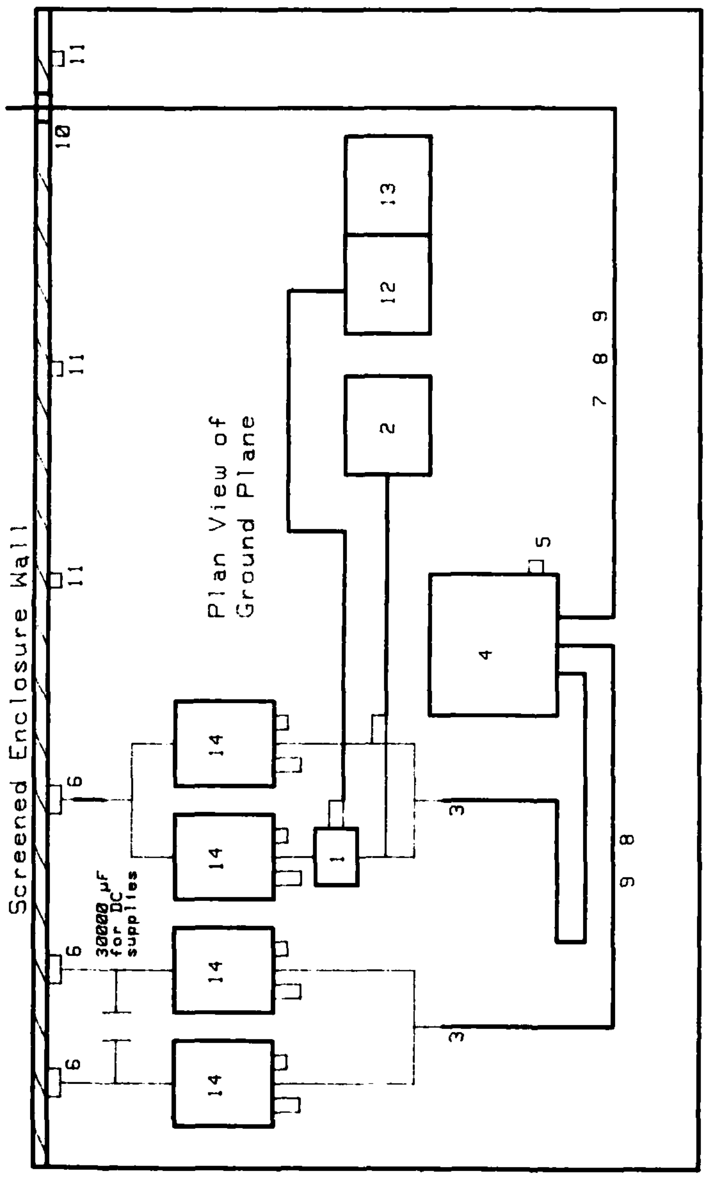
Care must be taken to ensure that the isolation transformer has adequate ratings, the maximum current required by the EUT must be less than that required to cause saturation or an unacceptable line voltage drop. Reference to the general requirements section is also required, especially paragraph 6.19.

If the transformer has a winding for the purpose of monitoring the injected voltages, this may be used provided the transformer is not in saturation.

5 Test Limits

The EUT shall not be susceptible to CW signals of the frequency and amplitude shown in Figure 24.

When the loop impedance of the power supply and EUT is low, high power will be required to achieve the test limit. The maximum power to be used for this test is limited, the test limit is deemed to be met is the voltage conditions cannot be achieved when the power settings produce 50 watts into a 0.5 ohm load substituted for the EUT circuit at the transformer secondary.



1. Audio Isolation Transformer
2. Oscilloscope/Voltmeter
3. EUT power leads, 1 metre total length, separated 300 mm from Audio Isolation Transformer
4. EUT situated with its face 100 mm +/- 20 mm from front edge of ground plane, where possible
5. Bond to ground plane for EUT's, as defined
6. Filtered power supply terminals at screened enclosure wall
7. EUT interconnecting lead; length as defined in the Test Set-Up
8. Power leads and interconnecting leads to be situated 100 mm +/- 20 mm from edge of ground plane where possible
9. Power leads and interconnecting leads to be supported 50 mm above ground plane level via insulated stand-offs
10. Interconnecting lead to monitoring equipment/test set via feedthrough connectors or feedthrough filters
11. Ground plane dc bond to screened enclosure wall shall be less than 2.5 milliohms
12. Audio Amplifier. 13. Audio Signal Generator.
14. LISN, 50 ohm termination, and 10 µF feedthrough capacitor bonded to ground plane

Figure 22 : Typical Test Configuration for Test Method ACS 01

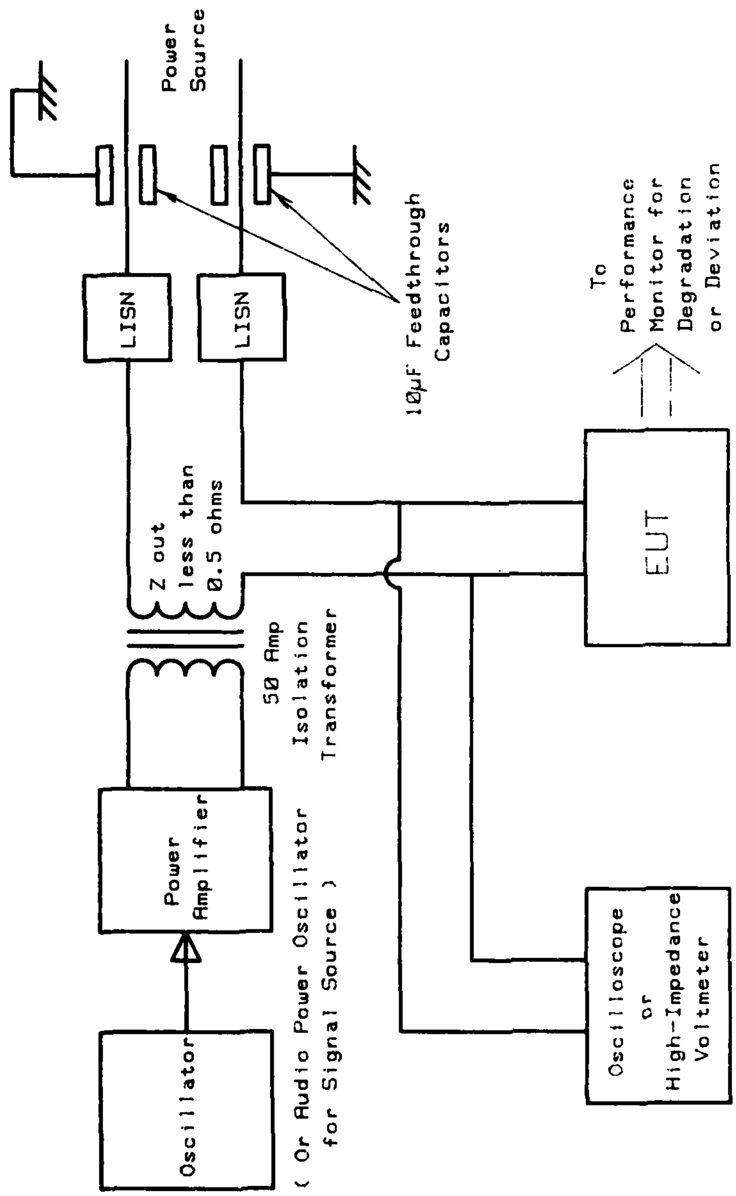


Figure 23 : Detailed Test Configuration; ACS 01: Conducted Susceptibility Power Leads

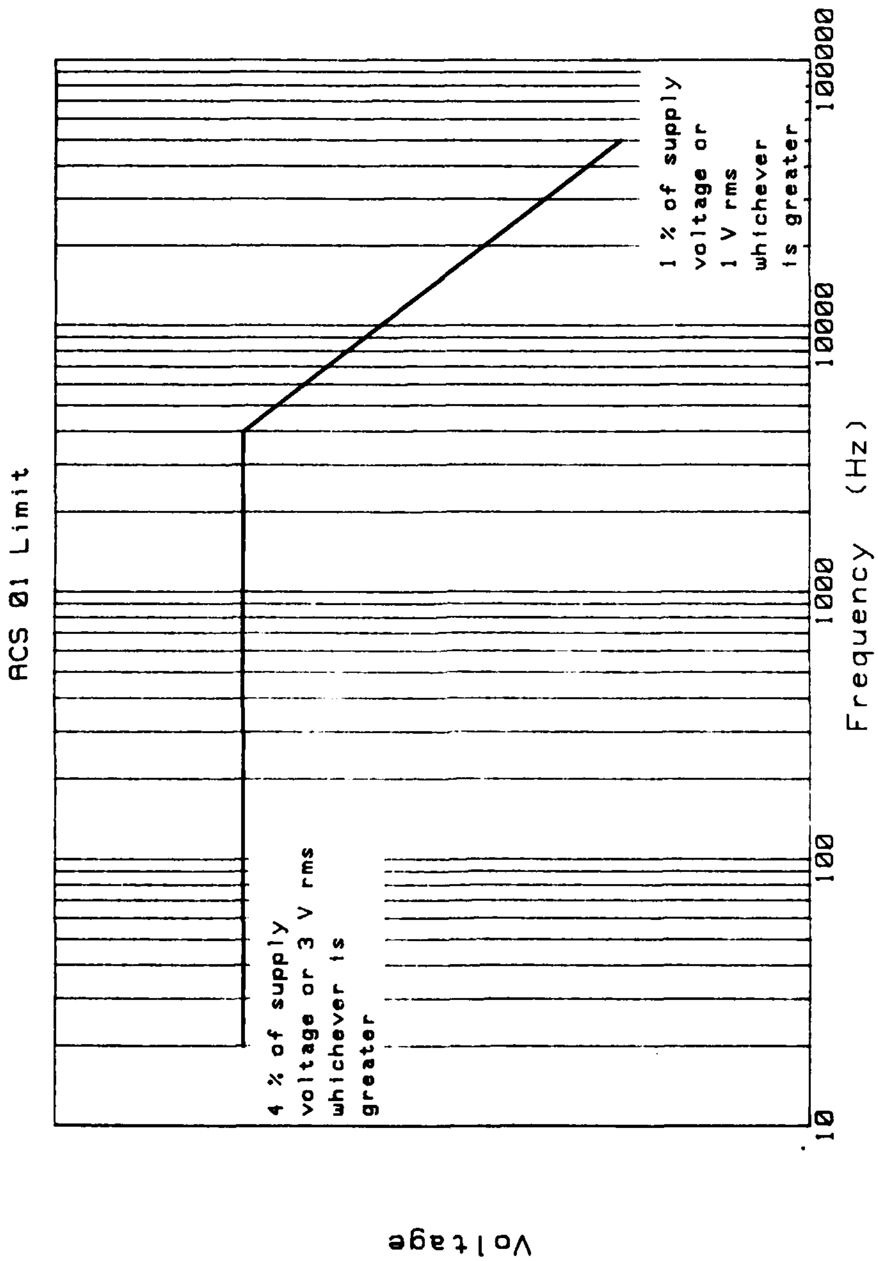


Figure 24 : Limit for Test Method ACS 01; Power Leads,
20 Hz to 50 kHz

SECTION 7.5

ACS 02 CONDUCTED SUSCEPTIBILITY, POWER, CONTROL AND SIGNAL LEADS 50 kHz to 400 MHz

1 Purpose

The purpose of this test is to confirm that rf signals in the range 50 kHz to 400 MHz, when coupled on to an EUT's interconnecting cable looms and power supply lines, will not cause either degradation of performance or malfunction. In addition it will provide an amplitude/frequency malfunction signature for the system which, when compared with the levels of current on the looms (or cables) due to the effects of onboard and external transmitting sources and measured during clearance to service trials, will assist in the determination of adequate safety margins.

2 Applicability

Cable looms which connect the EUT to other equipments in the aircraft system (including primary power lines) or those interconnecting units of the EUT are subject to this test. Cable looms can be tested as a whole or individual wires can be tested. The looms or individual wires to be tested will be defined in the equipment test plan but some basic ground rules are:-

(a) All looms will be tested as a whole, connector by connector.

(b) Primary power lines shall in addition be tested individually, injecting and monitoring on each line in turn.

(c) On flight safety critical equipment (including sub-systems responsible for the control and/or initiation of electro-explosive devices) individual wires or loom branches may be selected by the Technical Authority for testing in addition to (a) and (b) above.

(d) For a system with built in redundancy, eg a quadruplex flight control system, simultaneous injection on several looms may be required by the Technical Authority.

3 Test Layout

Section 6 should be studied before commencement of test. Figure 25 shows the layout for the test.

4 Apparatus

(a) Current injection probes	AIL 93686-1	50 kHz to 2 MHz
	36A	2 MHz to 200 MHz
	37A	200 MHz to 400 MHz

(b) Calibration jig for the current injection probes.

(c) Current monitoring probes - 50 kHz to 400 MHz.

(d) Signal source - 50 kHz to 400 MHz.

(e) 200 W power amplifier - 50 kHz to 400 MHz.

This amplifier must be capable of supplying the full rated power into the current injection probes (which have a high VSWR) with a harmonic content of less than 10%.

(f) Spectrum analyser or measuring receivers - 50 kHz to 400 MHz.

(g) Directional coupler - 50 kHz to 400 MHz (e.g. Amplifier Research DC2000).

No other injection probes may be used for the purposes of (a) without the express permission of the Technical Authority.

5 Test Method

5.1 General

Because of the wide range of circuit impedances and resonances, it is impractical to define the test limits in terms of the current flow in the loom or wire under test. Instead the limits are in terms of the forward power to the injection probe which gives defined currents in the calibration jig.

The test procedure has two main elements:

(i) Calibration of the current injection probes, which must be done prior to each equipment test or series of consecutive tests.

(ii) The equipment test.

5.2 Calibration procedure for injection probe

The following calibration procedure shall be performed prior to the test or series of tests using the same test equipment layout and probes as will be used for the test. The injection probe shall be installed in the calibration jig as shown in Figure 26. Constructional details of the calibration jig are given in RAE Tech. Memo. FS(F)588. The calibration jig shall be terminated in a 50 ohm 50 W rf coaxial load at one end and a 50 ohm spectrum analyser or rf voltmeter at the other. (See Figure 26). A 50 W power attenuator will be required to protect the spectrum analyser. The VSWR of the terminations at both ends of the calibration jig shall be less than 1.2:1 over the frequency range of the test. The injection probe is fed with power from the signal source via the power amplifier. The limits specified for this test method are in terms of current induced in the calibration jig. Two levels are used:

(a) An accept/reject level up to which the performance of the EUT should not be affected.

(b) A test level which is higher than the accept/reject level, up to which the equipment is tested to enable a malfunction signature to be obtained for the line or cable loom under test. The EUT must be capable of being tested to this higher level without permanent damage.

The test signal supplied to the injection probe shall be increased until the voltmeter or spectrum analyser indicates that the accept/reject level of current shown in Figure 27 is flowing in the calibration jig. The forward power flow to the probe shall be recorded. The power shall be increased until the test level current shown in Figure 27 is reached, and the forward power flow again recorded. These measurements are to be made over the frequency range 50 kHz to 400 MHz at sufficient intervals to ensure that amplitude variations are less than 1 dB between each measurement point.

The calibration curves shall be shown in the test report. The forward powers to the current injection probes to give the two levels of current shall become the accept/reject level and the test level respectively, for the equipment test.

5.3 Equipment Test

(a) This test may be applied to whole cable looms or individual conductors, those to be tested being defined in the equipment test plan. As a minimum requirement, the injection probe shall be connected around the complete cable loom and subsequently around any branches of that loom. In all cases the current monitor probe shall be connected around the complete cable loom 50 mm from the connector (see (c) below).

(b) The calibration procedure described above shall be performed prior to the commencement of the tests.

(c) The current monitor probe, which is used to measure the current actually induced on the loom or conductor under test, shall be fitted around the loom or conductor under test such that the face of the monitor probe nearest the EUT's connector is 50 mm from that connector (Figure 28). If the overall length of the connector and backshell exceeds 50 mm, the monitor probe shall be placed as close to the connector's backshell as possible and its position noted in the test report.

(d) The current injection probe shall be fitted around the loom or conductor under test such that the separation of the adjacent faces of it and the current monitor probe is 50 mm. However if the length of the loom is less than 0.5 m then the injection probe shall be placed in the centre of the loom and the induced current measured 50 mm from each connectors backshell.

(e) Prior to commencement of the test on each loom as defined under 2a a swept measurement of induced current per unit forward power to the injection probe shall be made. The power level to the injection probe should be of the order of 1 mW. This test can be accomplished using the test set up of Figure 28 but using a spectrum analyser with tracking generator. The measurements shall be graphically recorded in the test report, with the induced current normalised for a forward power of 1 watt. This information will aid the clearance agency in assessing how well the test installation simulated the aircraft installation. These results should also be referred to when measuring the malfunction signature in (f) to ensure resonances in the coupling are covered.

(f) At each test frequency, the signal amplitude shall be gradually increased from zero until malfunction occurs or the test level is reached. Two parameters shall be recorded: the induced current in the loom or wire (50 mm from the connector under test as measured by the monitor probe) and the forward power to the injection probe. The induced current will be used to provide information to the aircraft clearance agency and the forward power shall be assessed against the accept/reject level. Complete frequency coverage should be obtained by slowly sweeping between each test frequency to ensure the lowest susceptibilities have been found and the full malfunction signature is measured. Care must be taken to ensure "window effects" i.e. a malfunction which appears and then disappears with increasing injected power are not missed. The applied rf injection signal shall be modulated in accordance with the requirements of section 6.23.

(g) At frequencies where the EUT is susceptible, the signal amplitude shall be reduced until a threshold of susceptibility is determined. Check for hysteresis in signal amplitudes by decreasing and then increasing through the susceptibility threshold. The lesser of the two shall be recorded.

(h) The equipment will have to be designed to withstand the overtest level without suffering permanent damage.

6 Test Limits

The EUT shall not be susceptible to cw or modulated signals at or below the accept/reject level at any frequency in the range 50 kHz to 400 MHz. The modulation used shall be defined in the equipment test plan. When using modulated signals the amplitude shall be that indicated by the peak detector of an EMI receiver.

The EUT shall be subjected to increasing power up to the test level as defined above and Figure 27 or until malfunction, whichever is the sooner, in order to establish malfunction thresholds above the test level without suffering damage. The maximum injected current shall also be limited to 200 mA (50 kHz - 2 MHz) and 1A (2 - 400 MHz) at the accept/reject level and double these figures at the test level.

NOTE - For systems with wiring feeding to or from external stores or controlling EED's the accept/reject level should be a minimum of 6 dB above that shown in Figure 27. The test level shall be the same as shown as this is limited by the injection probe characteristics. The maximum current at the accept/reject level in this case shall be limited to 400 mA (50 kHz - 2 MHz) and 2A (2 - 400 MHz) and double these figures at the over test level.

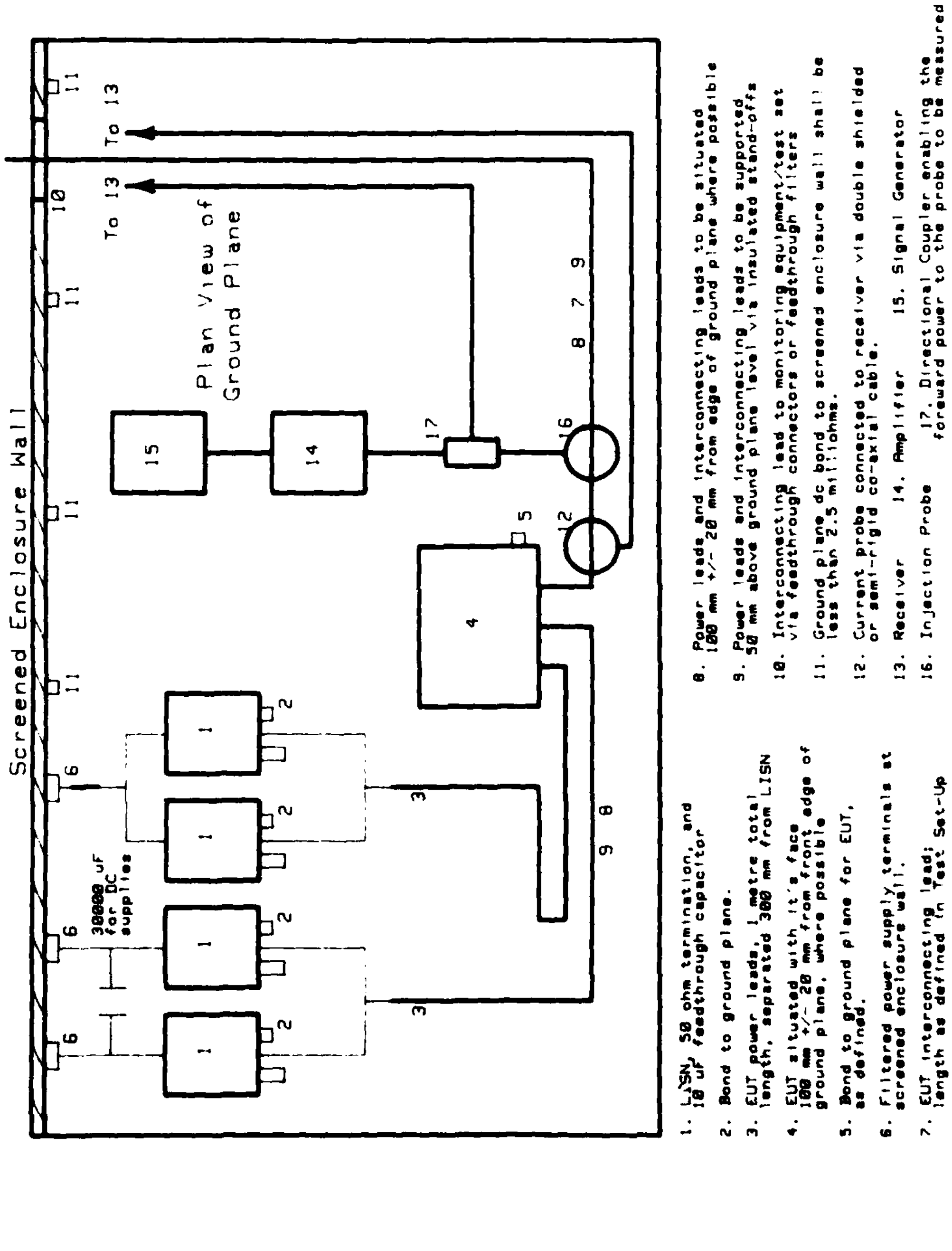


Figure 25 : Typical Test Configuration for Test Method ACS 02

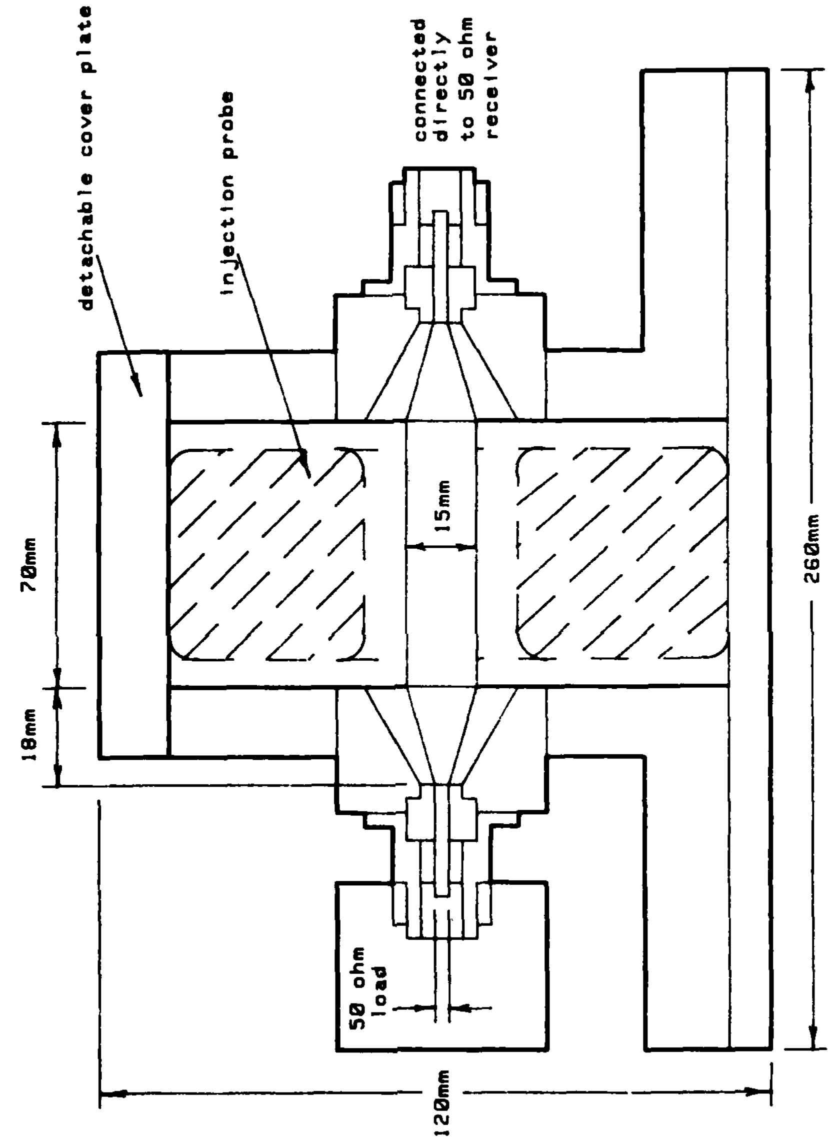


Figure 26 : Test Configuration for Calibration of Injection Probe; Test Method ACS 02

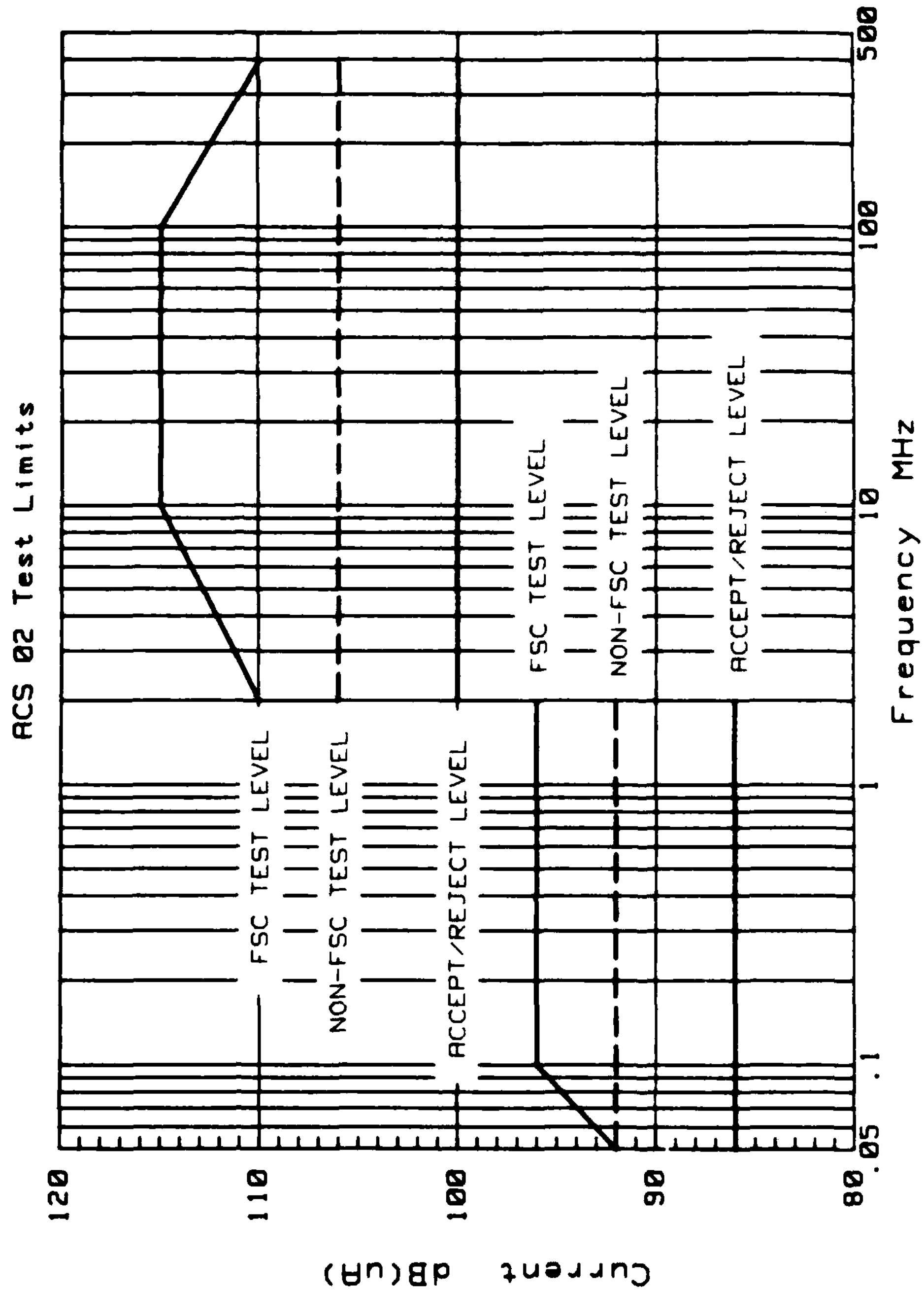


Figure 27 : Limits in Terms of Current that must be Induced in the Calibration Jig; Test Method ACS 02

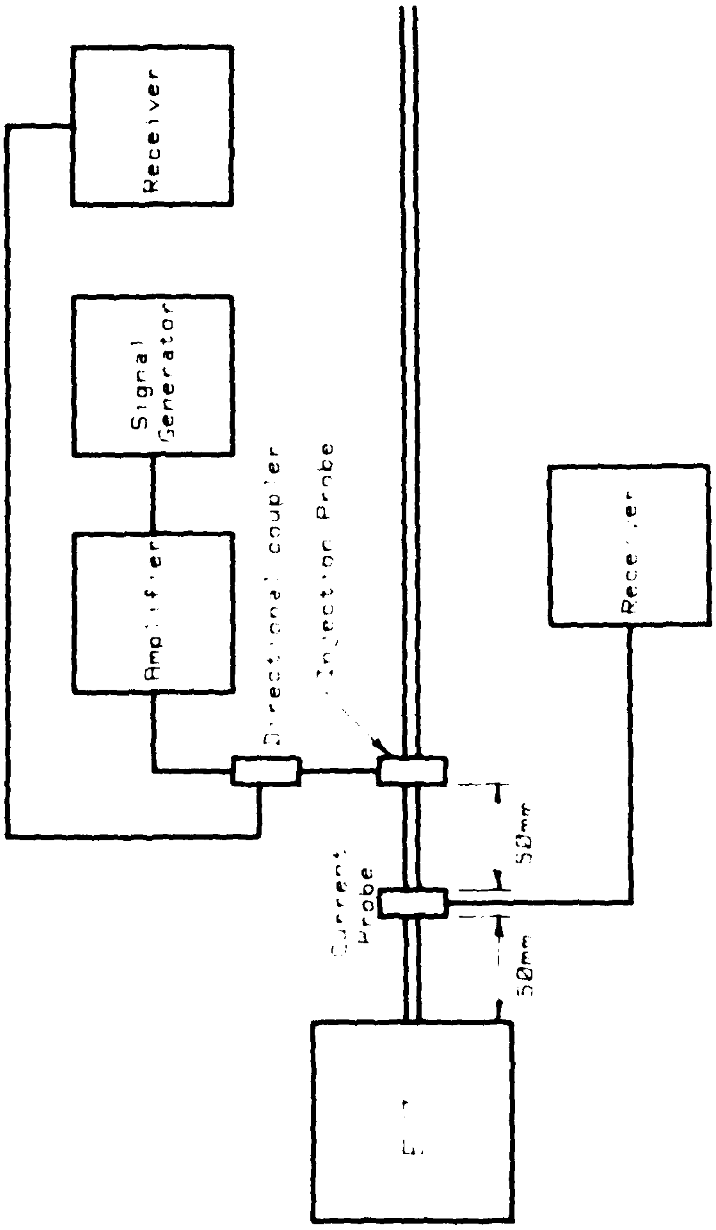


Figure 28 : Detailed Test Configuration; Test Method ACS 02

SECTION 7.6

ACS 03 CONDUCTED SUSCEPTIBILITY, CONTROL AND SIGNAL LEADS 20 Hz to 50 kHz

1 Purpose

The purpose of this test is to confirm that audio frequency signals coupled on to the control and signal leads of the equipment under test will not cause degradation of performance or malfunction.

2 Applicability

All control and signal cableforms are subject to this test.

3 Test Layout

Section 6 should be studied before commencement of test. Figure 29 shows a typical test set-up.

4 Test Method

The test set-up shall be as shown in Figure 30.

The test wire shall be closely coupled to each wire bundle or cable loom in the test set-up, in turn, by wrapping at a rate of two turns per metre cr a minimum of two turns.

The test signal shown in Figure 31 shall be applied to the test wire and swept over the frequency range 20 Hz to 50 kHz.

Throughout this sweep the EUT shall be monitored for malfunctions, or degradation of performance.

If susceptibility occurs the amplitude of the test signal shall be reduced to obtain a threshold condition and the frequency and amplitude recorded.

5 Test Limits

The EUT shall not exhibit any malfunction, degradation of performance or deviation from specified indication beyond the tolerances given in the EMC Test Plan when the signal shown in Figure 31 is applied to the test wire.

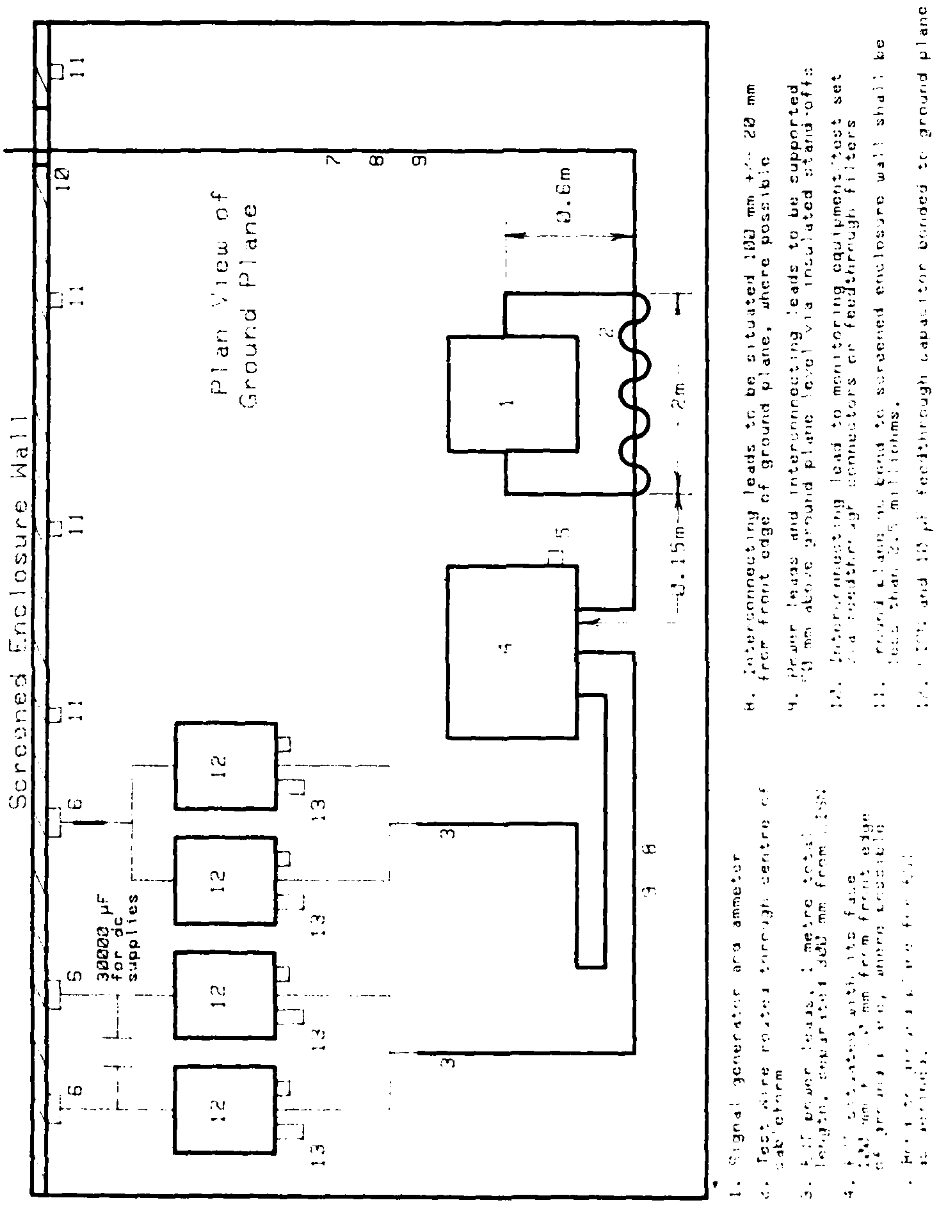


Figure 29 : Typical Test Configuration; Test Method ACS 03

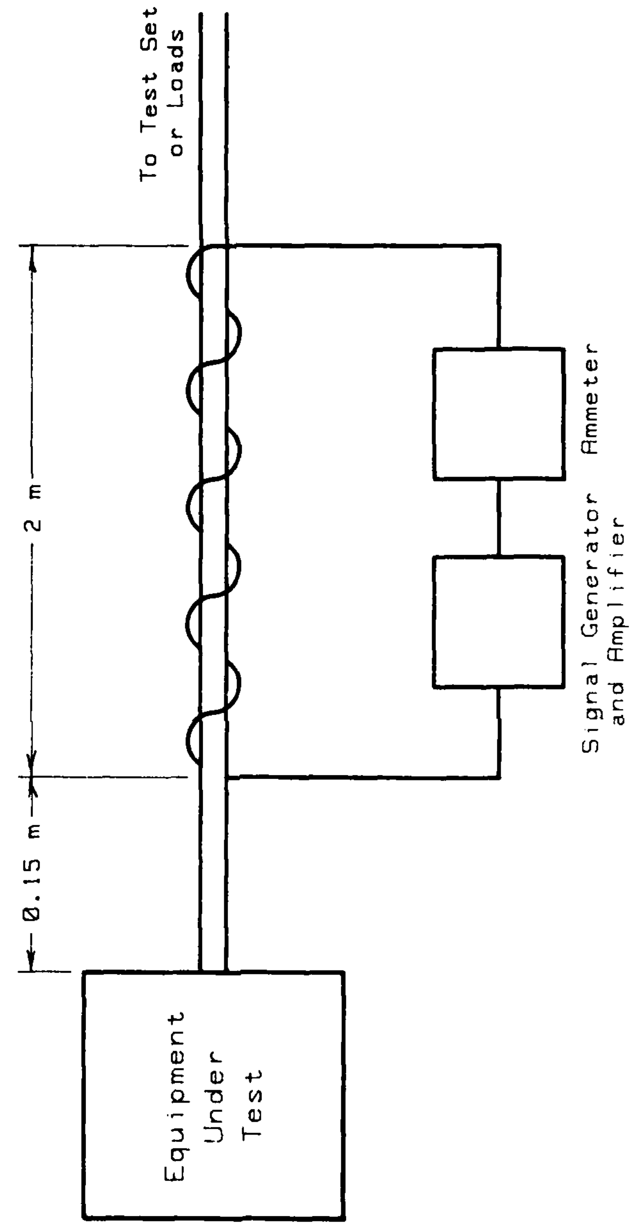


Figure 30 : Detailed Test Configuration for Test Method ACS 03.

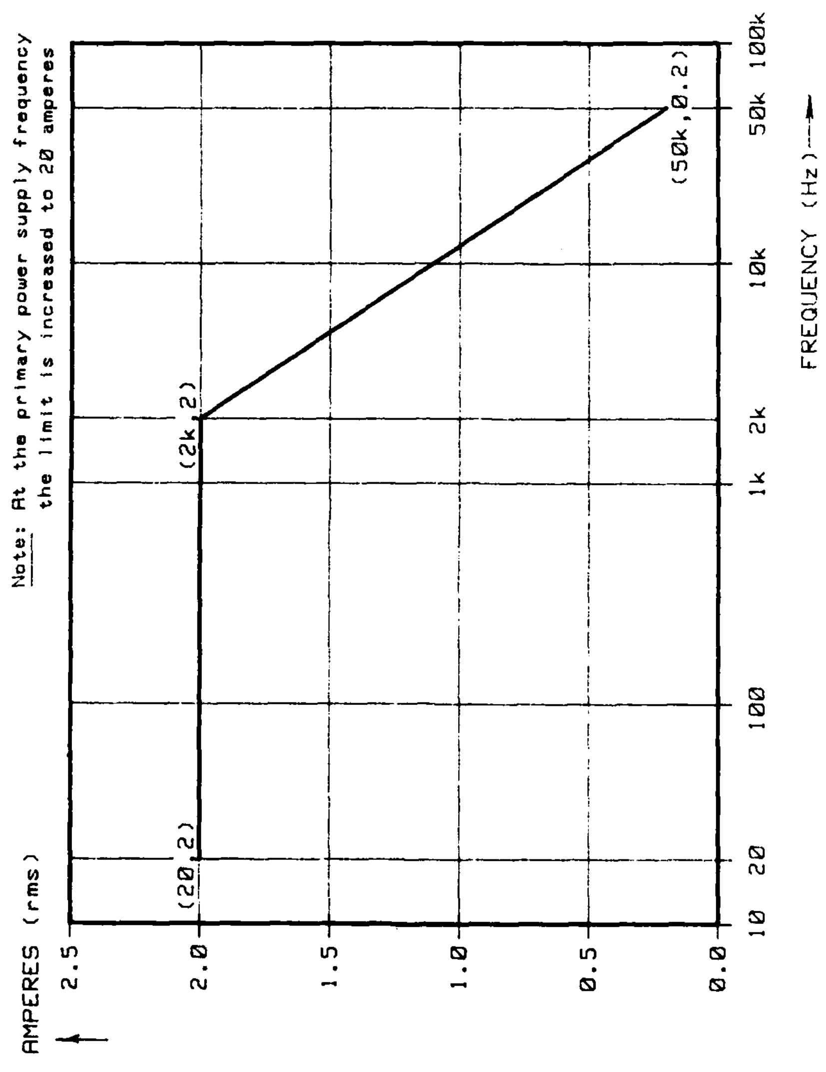


Figure 31 : Limit for Test Method ACS 03; Control and Signal Leads, 20 Hz to 50 kHz.

SECTION 7.7

ACS 04 CONDUCTED SUSCEPTIBILITY, IMPORTED TRANSIENTS, POWER, CONTROL AND SIGNAL LINES

1 Purpose

The purpose of this test is to ensure that transients of specified characteristics injected on to the power supply cables and on the interconnecting cables of EUT's will not cause damage, degradation of performance or malfunction. The transients shall be injected in the form of damped sinusoids, resonant at the frequencies at which susceptibility of the EUT is most likely to occur. These frequencies are determined from Paragraph 4 of the test method.

2 Applicability

EUT a.c. and d.c. power cables which interface with aircraft power supplies and cable looms which connect the EUT to other equipments in the aircraft system are subject to this test method. The test should not be applied to simulators included in the test arrangement.

As a minimum test requirement the following cable looms and power lines shall be tested for susceptibility to transients as defined in Section 6.25:-

(a) All looms (including primary power looms) shall be tested as a whole , connector by connector, for susceptibility to both Type 1 and Type 2 transients.

(b) Primary power lines shall in addition be tested individually and collectively for susceptibility to Type 2 transients only.

Additional tests may be required and should be detailed in the EMC test plan for the EUT.

3 Test Layout

Section 6 should be studied before commencement of this part of the test, especially Sections 6.18 and 6.25 which define the performance requirements of the oscilloscope systems, transient generators and injection probes to be used. Figure 32 shows a typical test layout for test ACS 04.

4 Test Method

4.1 General

The test procedure is based on the bulk current injection technique and uses specially designed injection probes. However, before the transient injection test can be applied it will be necessary to measure the rf impedance of the various cable looms to be tested, over the frequency range 2 to 30 MHz. These measurements will determine the frequencies where the cables have maximum and minimum impedance (i.e. maximum voltage and current coupling to the cable).

The test has two main sections, (a) selection of the transient injection frequencies from cable impedance measurements and, (b) transient injection testing and monitoring EUT for susceptibility. For both of these tests it will be necessary to measure the induced cable current and the induced cable voltage. The current induced in the cables under test shall be measured by a suitable current probe. The voltage induced on the cables under test shall be measured using one of two methods depending on the type of cables under test.

(i) For injection on individual power lines, the differential voltage induced on the line shall be measured directly, using oscilloscope voltage probes connected to the power line 25 mm from the EUT connector.

(ii) For injection on interconnecting cables and groups of power lines, the injection probe shall be fitted with a short, low reactance, single turn monitor loop (around the probe) via an oscilloscope probe to measure the voltage induced by the probe on the cables (Figure 33).

The following table lists the injection probe location and voltage measurement locations required for testing various power lines for susceptibility to Type 2 transients :-

Power Line Injection and Voltage Measurement Locations: Type 2 Transients

POWER LINE UNDER TEST	INJECTION LOCATION	VOLTAGE MEASUREMENT AND LOCATION
28V d.c.	28V 0V 28V + 0V	28V to 0V 0V to GND MONITOR LOOP
115V 400 Hz	115V Neutral 115V + Neutral	115V to Neutral Neutral to GND MONITOR LOOP
3 Phase 400 Hz 115V/200V	Phase 1 Phase 2 Phase 3 Neutral Phase 1+2+3 Phase 1+2+3+Neutral	Phase 1 to Neutral Phase 2 to Neutral Phase 3 to Neutral Neutral to GND MONITOR LOOP MONITOR LOOP

Note: For power lines having no neutral line, the voltage measurements shall be made with respect to the ground plane. For Type2 transients both positive and negative polarities shall be applied by reversal of the injection probe. It should also be noted that for some types of measuring equipment some rejection of the power line frequency may be necessary to avoid "swamping" the low level cw voltage signal.

For primary power lines the tests shall be applied at the EUT connector end of the cable. For other cables, in excess of 1 metre in length, the test shall be applied in turn to each end of the cable. Interconnecting cables less than 1 metre long which are run in a dedicated loom are exempt from this test since the coupling to them will be very low. A spacing of 50 mm shall be maintained between the current probes and also between the measuring current probe and the connector of the EUT.

4.2 Selection of Transient Injection Frequencies

To measure the cable loom impedance, low level swept frequency cw signals are injected into the interconnecting cableforms or power lines under test over the frequency range 2 to 30 MHz, using the ERA 45 injection probe. The ratio of the injected cable voltage to the injected cable current is a measure of the cable impedance. The test set up for these measurements is shown in Figure 34 for measurements on individual power lines, and Figure 35 for measurements on groups of power lines and interconnecting cables. A plot of the cable loom impedance shall be included in the test report.

4.3 Transient Injection Testing

Having measured the cable loom impedances the transient injection testing shall take place. Transients shall be injected at the frequencies listed in the following three sections:-

(i) Fixed frequencies of 100 kHz, 2 MHz, 3, 5, 7, 10, 15, 20, 25 and 30 MHz.

(ii) The frequencies at which maximum and minimum cable impedances occur (found from the previous section, 4.2).

(iii) The most susceptible frequencies in the range 2 to 30 MHz found from the ACS 02 test, (assuming susceptibility was found).

The transients shall be injected using the test set up shown in Figure 36 for individual power lines, and Figure 37 for groups of power lines and interconnecting cables. At each test frequency the amplitude of the transient induced cable voltage and cable current shall be gradually increased until the test limit is reached (unless susceptibility occurs). The frequency of the transient generator shall also be finely tuned for maximum induced voltage and also maximum induced current where the cables are high impedance and low impedance respectively.

The transients shall be applied at a rate of at least 10 transients in a period of 5 minutes and the EUT monitored for degradation of performance damage or malfunction. It should be noted that for digital systems it may be necessary to apply the test for longer periods of time in order to determine failures. If required, this should be detailed in the EUT test plan. If susceptibility occurs, the amplitude of the transient shall be reduced to obtain a condition of threshold of malfunction and the transient repetition rate, phase position on the a.c. waveform (Type 2 transients only) and transient frequency (Type 1 transients only) varied for maximum susceptibility. The test report shall include details of the levels of transient voltage and current induced on the cables in addition to typical transient waveform oscillograms.

5 Test Limits

The maximum test limits and waveforms are shown in Figures 38 and 39 and are included in the following table and are in terms of either a maximum induced cable current or a maximum induced cable voltage, whichever occurs first, (assuming susceptibility does not occur). For primary power lines the voltage is measured directly on the power line, but for interconnecting cables the voltage is measured via the monitor turn around the injection probe.

Test Limits

Cable Under Test	100 kHz Transients		2 to 30 MHz Transients	
	Peak V (volts)	Peak I (amps)	Peak V (volts)	Peak I (amps)
Power Lines	700	30	500	20
Control and Signal	100	5	500	20

The limits have been derived from practical measurements carried out at RAE and also from an examination of the results of existing literature on aircraft transient measurements.

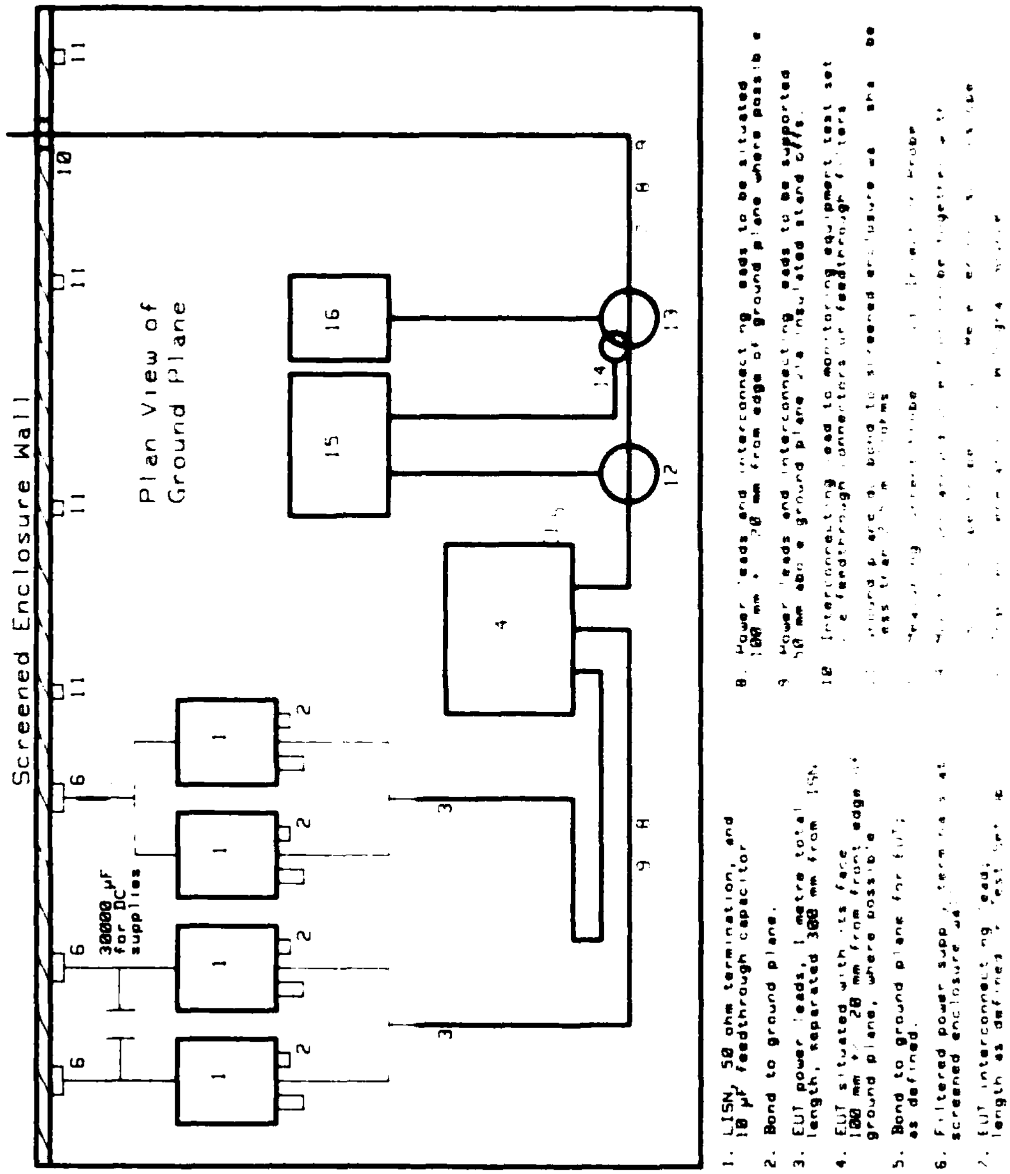


Figure 32 : Typical Test Configuraton; Test Method ACS 04.

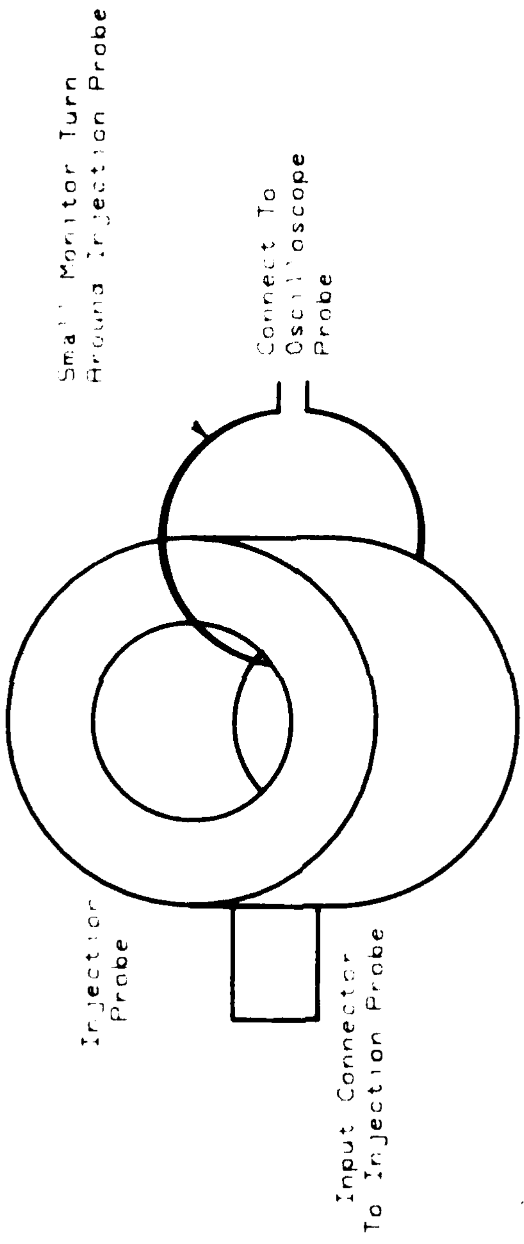


Figure 33 : Monitor Loop for Injection Probe; Test Method ACS 04.

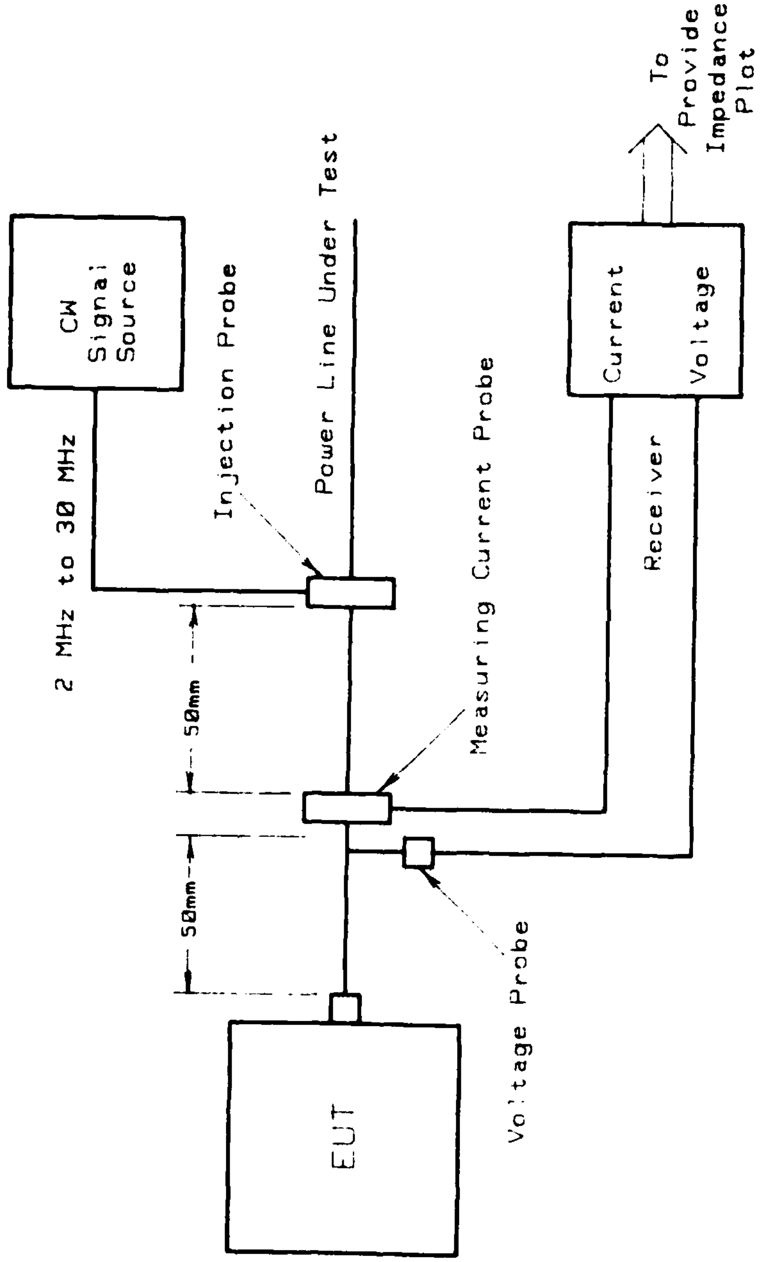


Figure 34 : Test Configuration for CW Impedance Measurements, Single Power Lines; ACS 04.

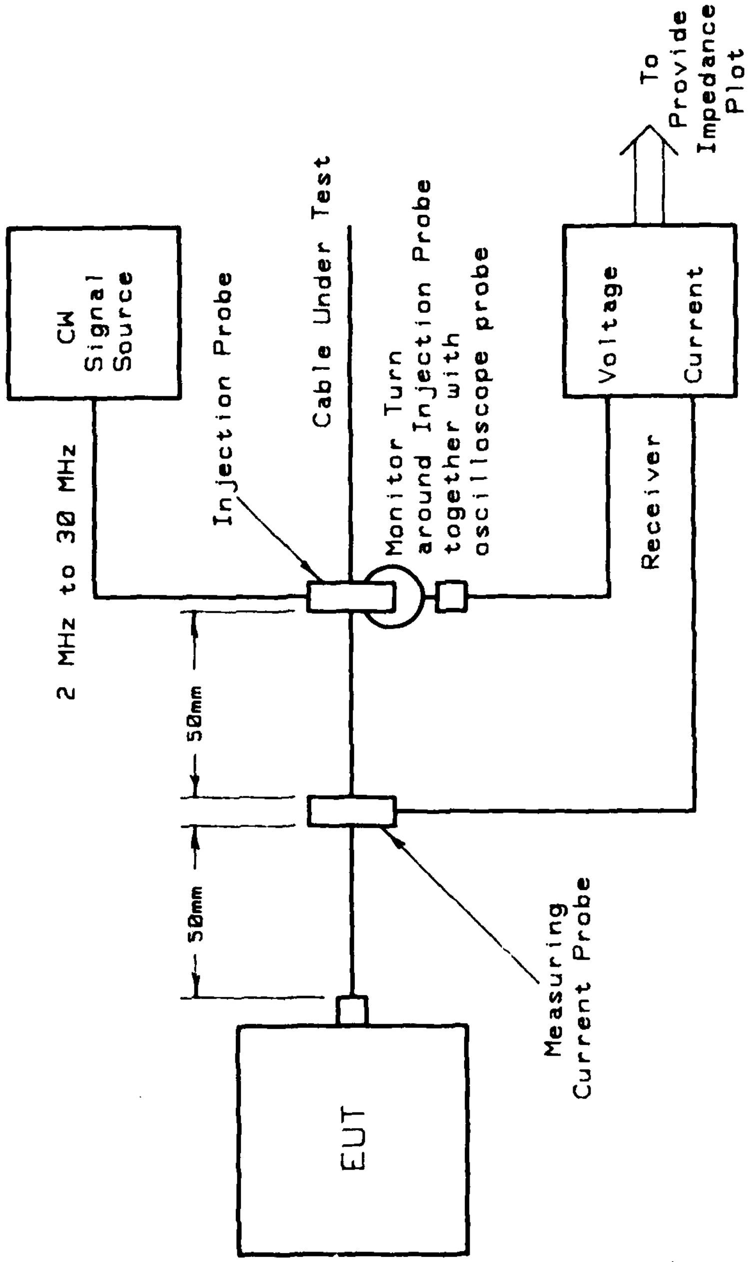


Figure 35 : Test Configuration for CW Impedance Measurements, Multiple Cables; ACS 04.

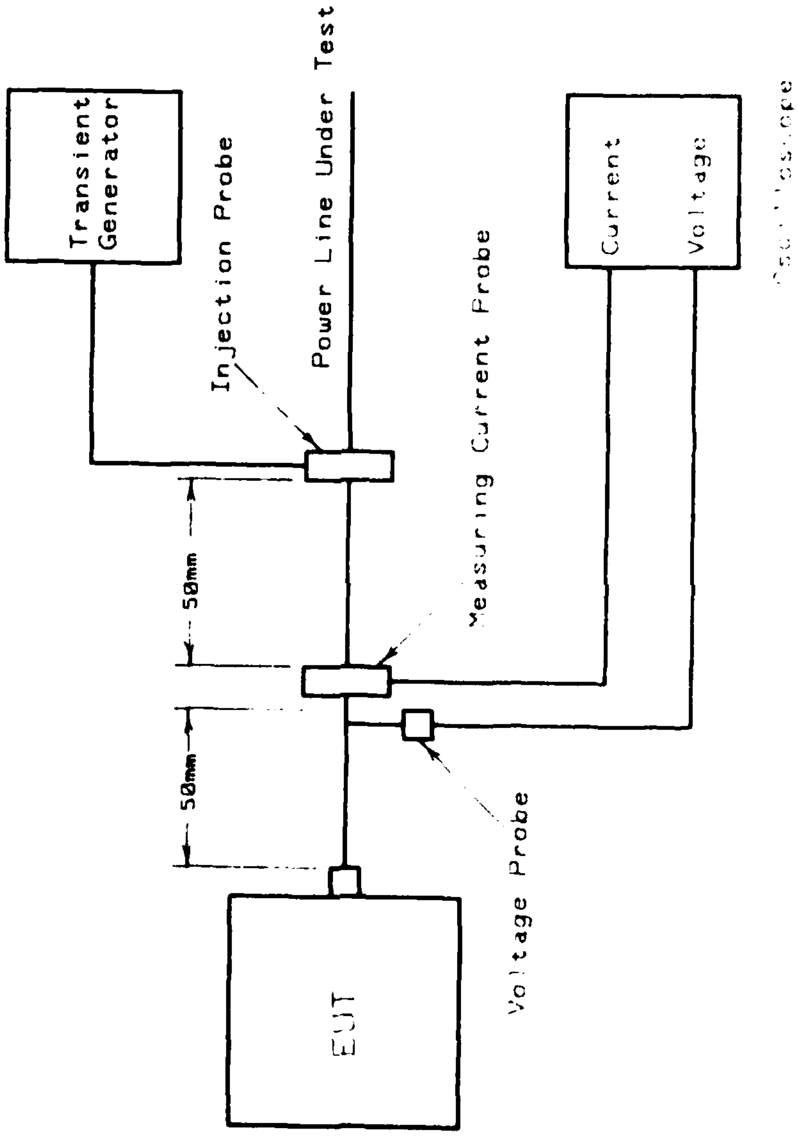


Figure 36 : Test Configuration for Transient Injection, Single Power Lines; ACS 04

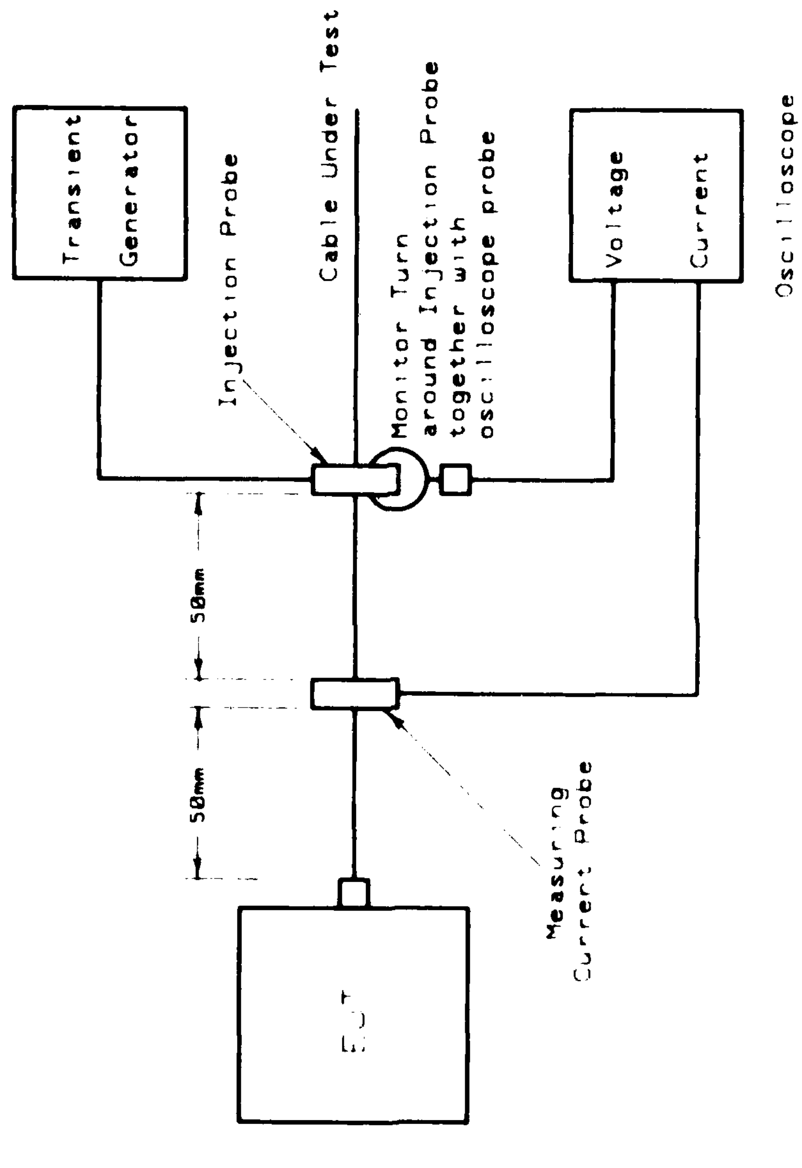


Figure 37 : Test Configuration for Transient Injection, Multiple Cables; ACS 04.

CABLE UNDER TEST	TYPE 1 TRANSIENTS 2 MHZ TO 30 MHZ PEAK V	PEAK I
POWER LINES	500 V	20 A
CONT. AND SIG.	500 V	20 A

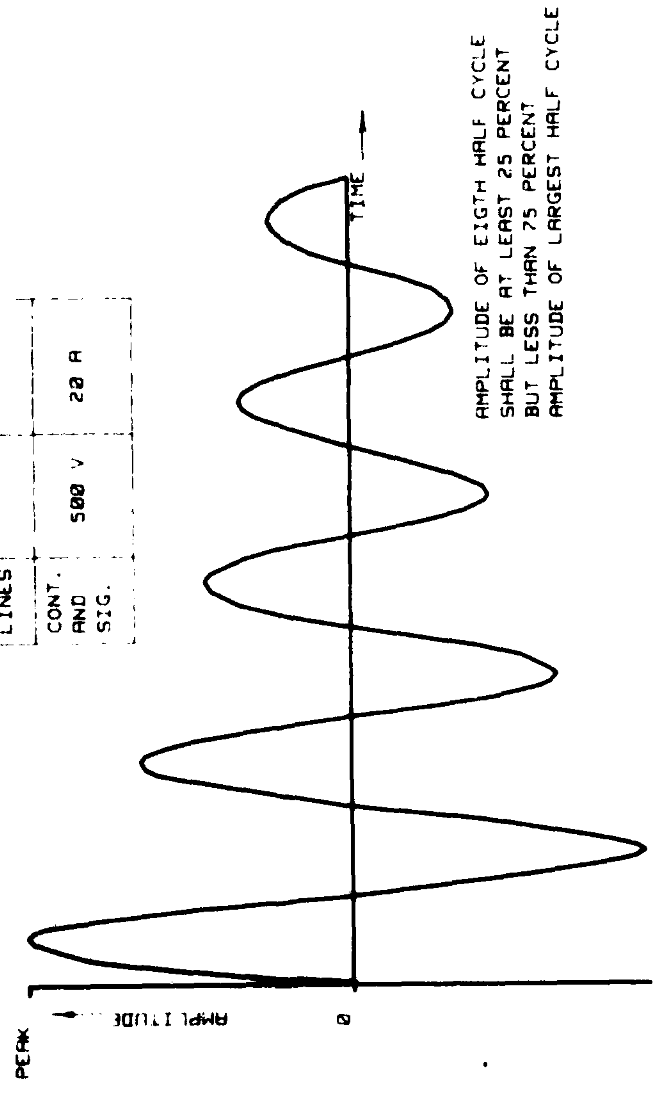


Figure 38 : Limit for Test Method ACS 04; Type 1 Transients.

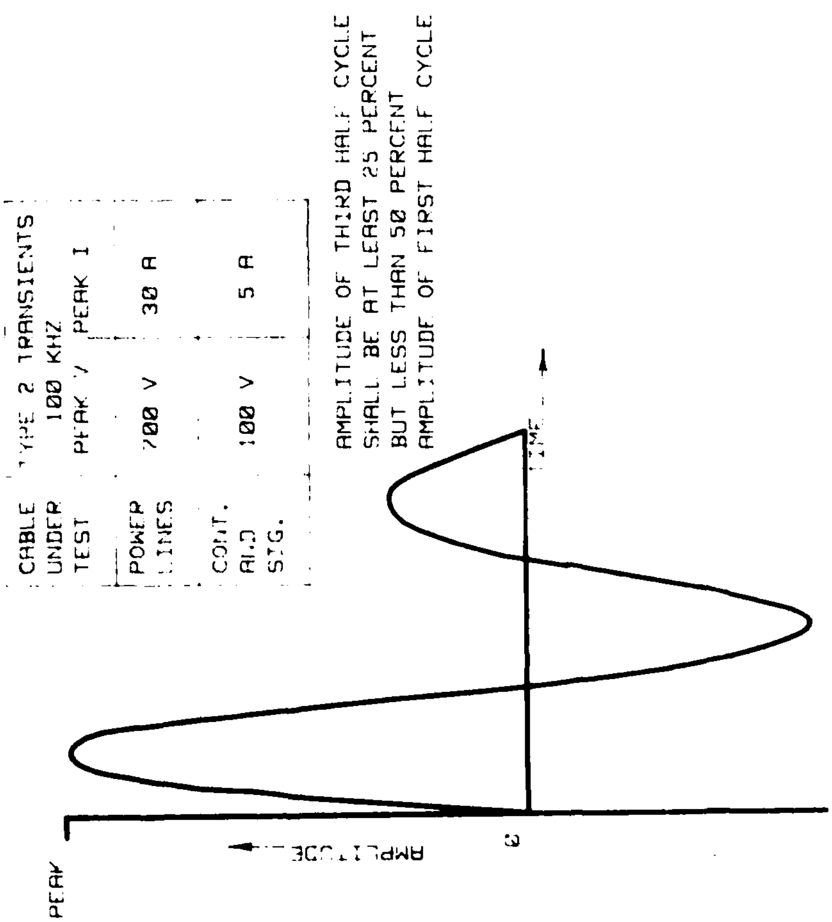


Figure 39 : Limit for Test Method ACS 04; Type 2 Transients.

SECTION 7.8

ARE 01 RADIATED EMISSION, MAGNETIC FIELD, 20 Hz TO 50 kHz

1 Purpose

In order to achieve compatibility between modern equipments operating together, limitations on emissions and control of susceptibility must be clearly defined. The levels of H field related to both emissions and susceptibility have been formulated from composite measurements taken in equipment bays and an average level of interference established.

Since these levels are realistic, equipment should be designed to operate satisfactorily in this environment. It may be found impracticable to meet the emission limits for some equipments in which case if the distance at which the amplitude limit level is met for the equipment under test, segregation by that distance from other equipment or cabling may offer a realistic alternative.

2 Applicability

All EUT units i.e. boxes, cases or cabinets.

3 Test Layout

A test layout is shown in Figure 40 but reference to the general requirements section is also required, especially paragraph 6.27.

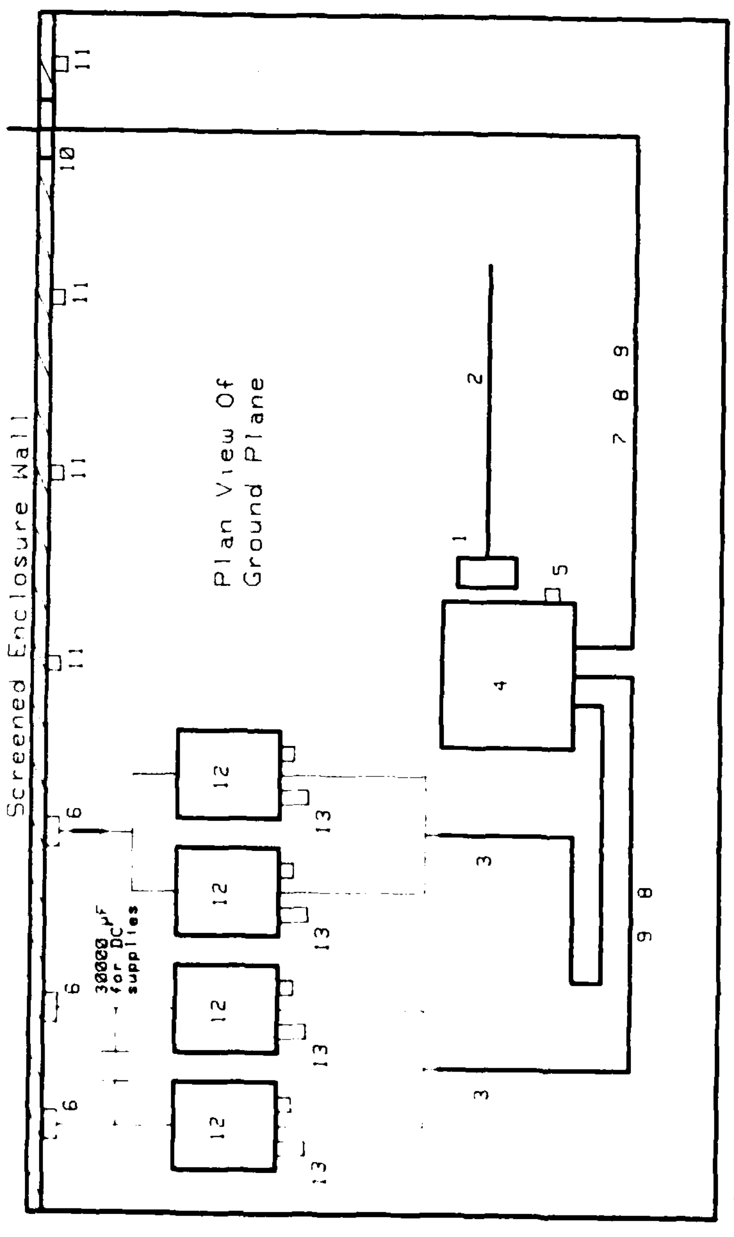
4 Test Method

A field measuring device in the form of a multi-turn loop shall be placed 70 mm from each face of the EUT with connection to a suitable frequency selective voltage measuring equipment with the plane of the loop parallel to the face of the EUT as shown in Figure 41. Particular attention should be given to the critical frequencies of the EUT.

In the event of the EUT exceeding the specified limit at 70 mm, the distance at which compliance is achieved shall be recorded.

5 Test Limits

Limits for the test shall be as shown in Figure 42.



1. Loop (magnetic field) positioned 70 mm from face of EUT and connected to receiver
2. Double shielded or semi-rigid co- axial cable
3. EUT power leads, 1 metre total length
4. EUT situated with its face 100 mm +/- 20 mm from front edge of ground plane, where possible
5. Bond to ground plane for EUT, as defined
6. Filtered power supply terminals at screened enclosure wall.
7. EUT interconnecting lead; length as defined in Test Set-Up
8. Power leads and interconnecting leads to be situated 100 mm +/- 20 mm from front edge of ground plane, where possible
9. Power leads and interconnecting leads to be supported 50 mm above the ground plane level via insulated stand-offs.
10. Interconnecting lead and monitoring equipment/test set via feedthrough connectors or feedthrough filters
11. Ground plane dc bond to screened enclosure wall shall be less than 2.5 milliohms.
12. LISN and 10µF feedthrough capacitor bonded to ground plane.
13. 50 ohm termination for LISN

Figure 40 : Typical Test Configuration; Test Method ARE 01

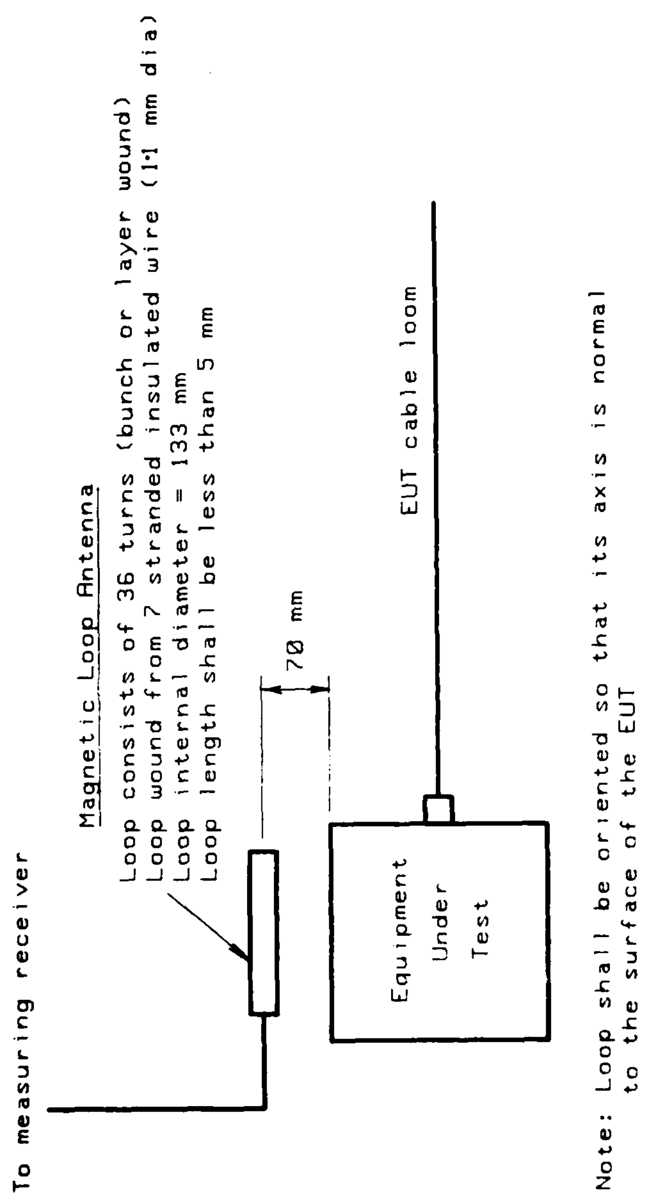


Figure 41 : Test Antenna and Detailed Test Configuration for Test Method ARE 01.

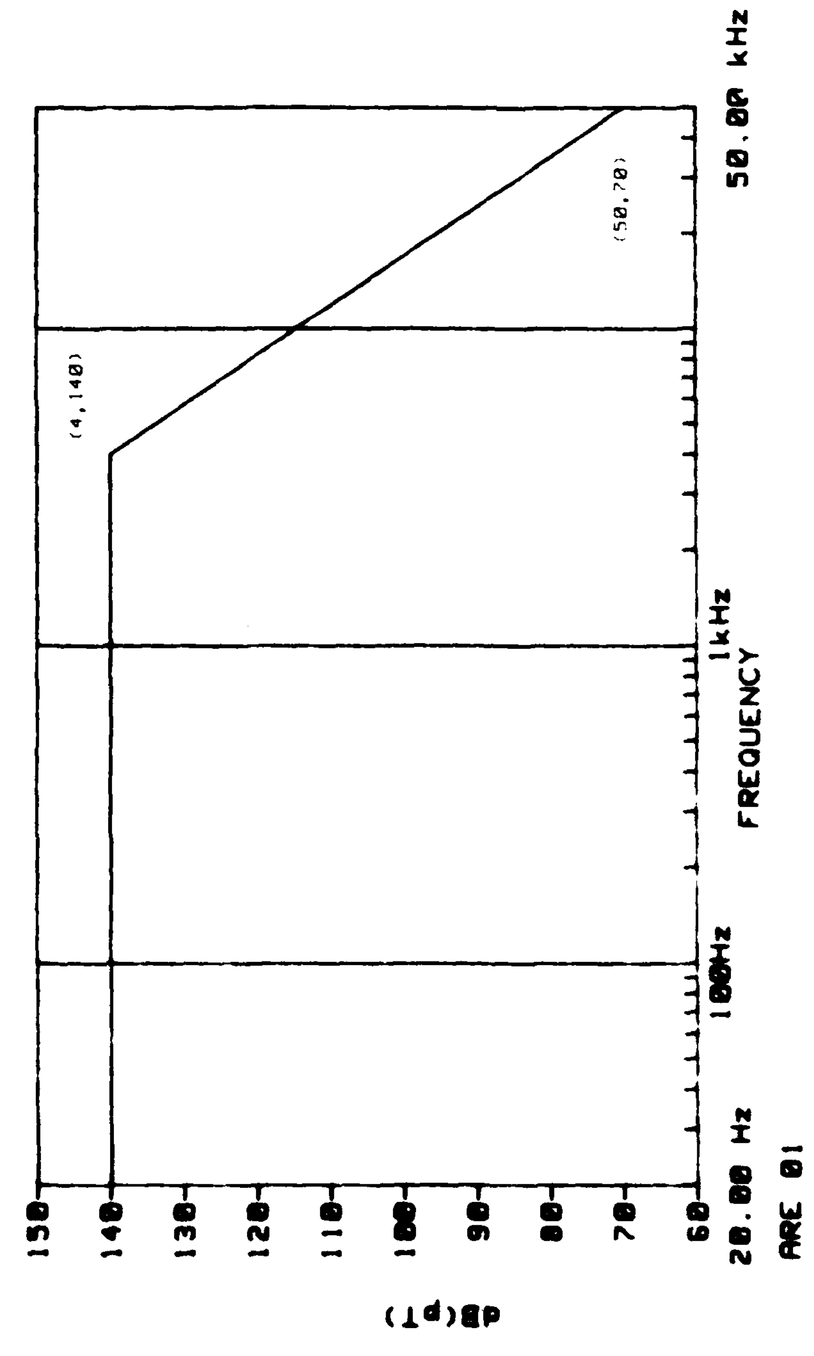


Figure 42 : Limit for Test Method ARE 01; Radiated Emission Magnetic Field, 20 Hz to 50 kHz.

SECTION 7.9

ARE 02 RADIATED EMISSION, ELECTRIC FIELD, 50 kHz to 18 GHz

1 Purpose

The purpose of this test is to confirm that the electric field emissions from the equipment under test including cables and interconnecting wiring are not greater than the acceptable specification limits.

Electric field emissions from the EUT may couple to other nearby susceptible cables and equipments installed in the aircraft. Thus, the objective of this EMI test is to ensure that these emission levels will not be likely to result in a radiated EMI problem via the electric field coupling media.

2 Applicability

The EUT including cables and interconnecting wiring are subject to this test method. All radiations emanating from antennas, where antennas apply, are excluded for this test method.

3 Test Layout

Section 6 should be studied before commencement of test. Figure 43 shows a typical test layout.

4 Test Method

The equipment shall be connected as shown in Figure 43.

The antenna shall be located at 1 metre distance from the maximum emission area(s), if known otherwise it should be placed opposite the mid-point of the EUT.

The orientations and distances in paragraph 6.28 shall be used for positioning of the test antennas.

The extremities of the antennas shall not be closer than 1 metre to any wall, ceiling or floor of the shielded enclosure.

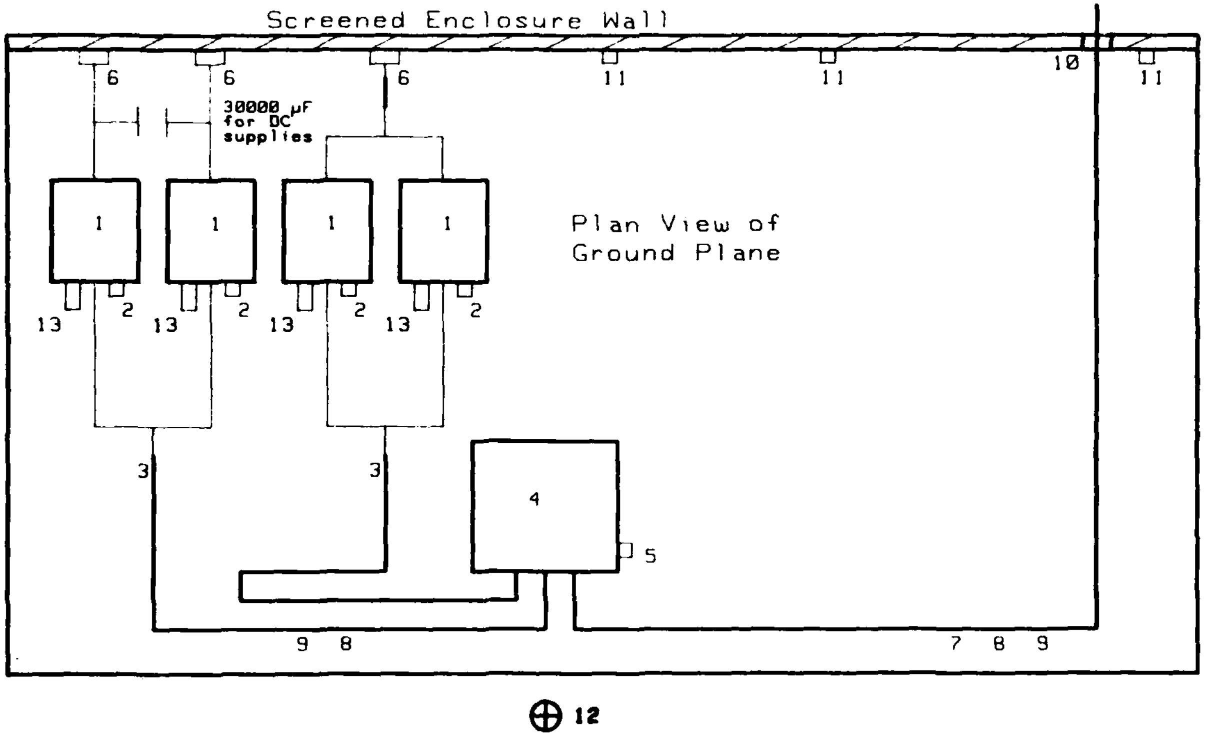
The radiated emissions shall then be plotted by semi-automatic or automatic means over the frequency range 50 kHz to 1 GHz. Spot frequency measurements are not allowed however if the interference is caused by a switching operation occurring less than once every 15 seconds the interference shall be measured at enough frequencies to describe the maximum level using manual techniques.

The receiver bandwidth shall be selected in accordance with paragraph 6.14.

Between 1 GHz and 18 GHz manual, semi-automatic or automatic means may be used. When manual measurements are made the frequency range shall be swept and all emissions recorded.

5 Test Limits

Electromagnetic emissions in the frequency range 50 kHz to 18 GHz shall not emanate from the EUT and its cableform in excess of the values shown in Figure 44.



1. LISN and 10μF feedthrough capacitor
2. Bond to ground plane
3. EUT power leads, 1 metre total length *separated at 300 mm from LISN*
4. EUT situated with it's face 100 mm +/- 20 mm from front edge of ground plane, where possible
5. Bond to ground plane for EUT, as defined
6. Filtered power supply terminals at screened enclosure wall
7. EUT interconnecting lead; length as defined in Test Set-Up
8. Power leads and interconnecting leads to be situated 100 mm +/- 20 mm from edge of ground plane whese possible
9. Power leads and interconnecting leads to be supported 50 mm above ground plane level via insulated stand-offs
10. Interconnecting lead to monitering equipment/test set via feedthrough connectors or feedthrough filters
11. Ground plane dc bond to screened enclosure wall shall be less than 2.5 milliohms
12. Antennas positioned as in Para 6.28 and connected to receiver via double shielded or semi-rigid co-axial cable.
13. 50 ohm termination for LISN

Figure 43 : Typical Test Configuration; Test Method ARE 02

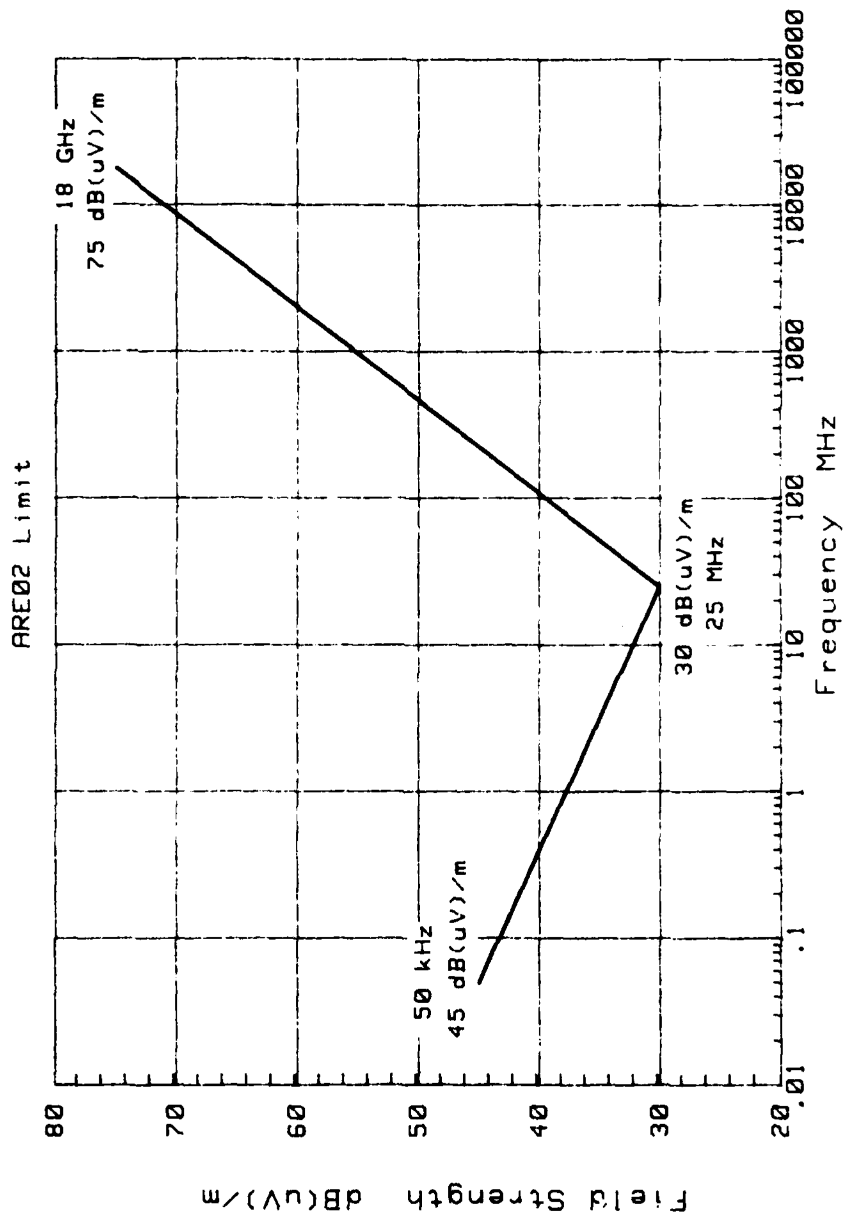


Figure 44 : Limit for Test Method ARE 02; Radiated Emission, Electric Field, 50 kHz to 18 GHz

SECTION 8.0

ARS 01 RADIATED SUSCEPTIBILITY, MAGNETIC FIELD 20 Hz to 50 kHz

1 Purpose

In order to achieve compatibility between modern equipments operating together limitations on emissions and susceptibility must be clearly defined. The levels of H field related to both emissions and susceptibility have been derived from extensive measurements of real life situations.

Since these levels are realistic, equipment should be designed to operate satisfactorily in this environment. It may be found impracticable to meet the susceptibility requirements for some equipments, in which case if the distance at which the amplitude limit level is met for the equipment under test, segregation by that distance from other equipment may offer a realistic alternative.

2 Applicability

All EUT units i.e. boxes, cases or cabinets.

3 Test Layout

Section 5 should be studied before commencement of test. Figure 45 shows a typical test layout. The design of the loop is shown in Figure 46.

4 Test Method

The equipment shall be set up as shown in Figure 45.

The field radiating loop shall be positioned 50 mm from the surface of the EUT's face with the plane of the loop parallel to the plane of the EUT's surface. This spacing is accomplished by the 50 mm spacer on the loop former (see Figure 46) being placed directly on the surface of the EUT.

The loop shall be supplied with sufficient current to produce magnetic flux densities at the specified level in Figure 46 at the test frequencies, by adjusting the oscillator drive to the test loop until the desired level is read by the EMI receiver. The field is defined as that recorded by the loop specified in the test method ARE 01 when the spacing between the centres of the loops is 50mm

The loop shall be moved over the EUT's surface, cableforms and connectors to determine the locations at which the applied field produces maximum susceptibility, if any.

For small EUT samples, not bigger than twice the loop diameter, the location of the loop shall be at the centre of the face of the EUT. The frequency scan shall then be performed. The loop shall then be relocated and the frequency scan again performed. For larger EUT's this same procedure shall be followed except many repetitions are required to complete the test.

With the frequency and loop at the location of maximum susceptibility, the loop current shall be adjusted until the performance of the EUT is no longer affected by the applied field. This will be the susceptibility threshold level to be recorded.

5 Test Limits

The EUT shall not exhibit any malfunction, degradation of performance or deviation from specified indication beyond the tolerances given in the EUT's individual equipment specification when subjected to the magnetic field levels shown in Figure 47. If it does malfunction, the distance at which conformity is acheived is recorded.

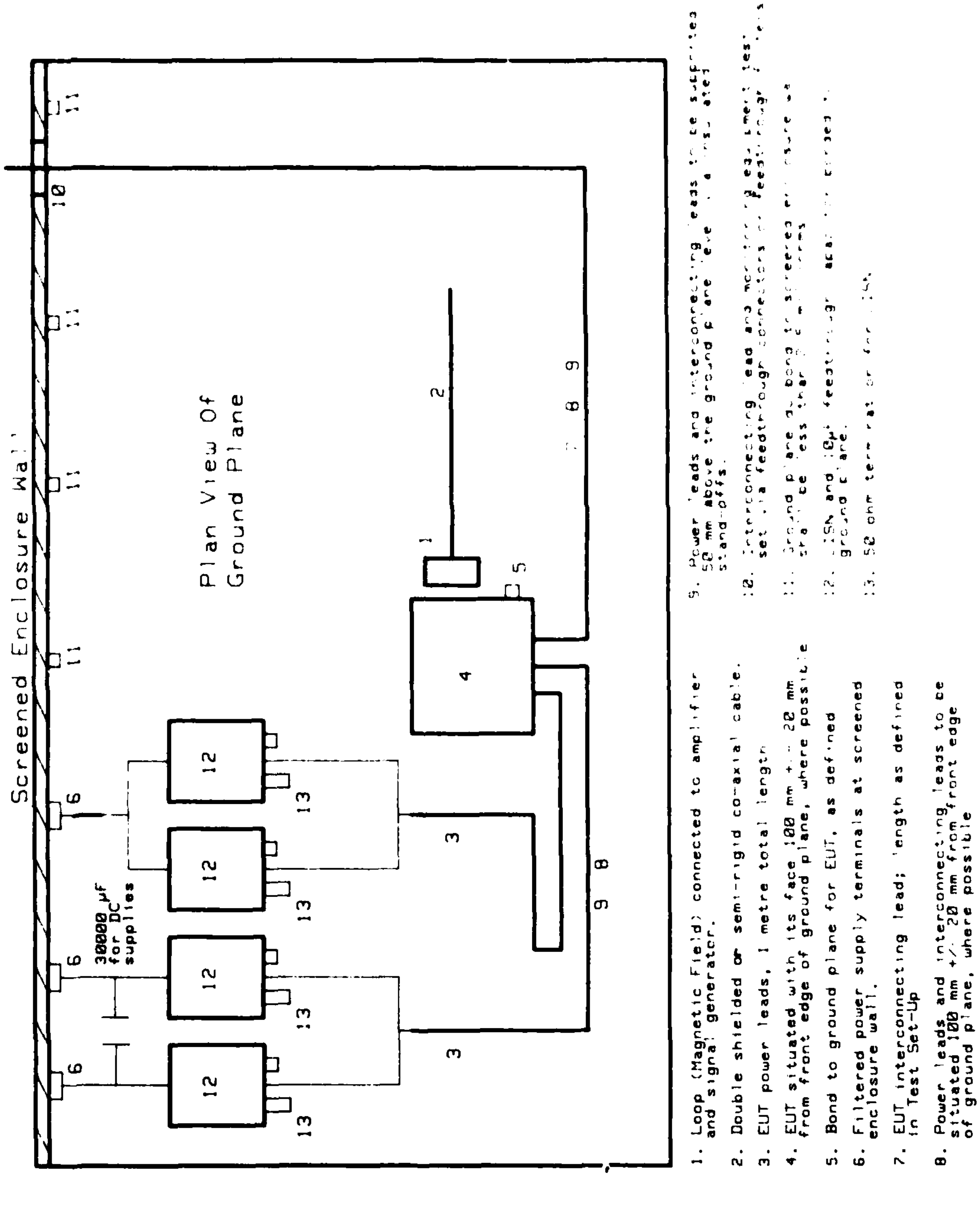


Figure 45 : Typical Test Configuration; Test Method ARS 01

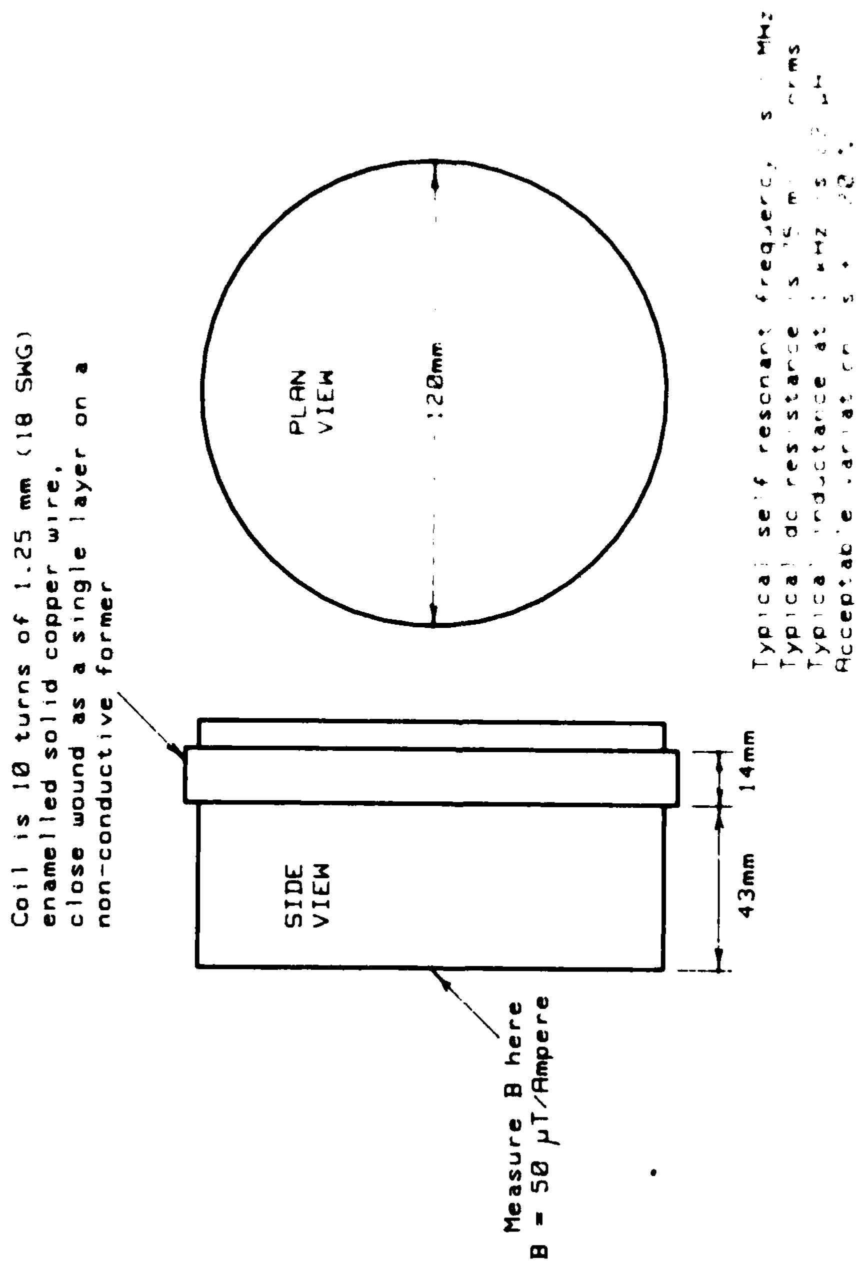


Figure 46 : Design of the Loop Antenna for Test Method ARS 01

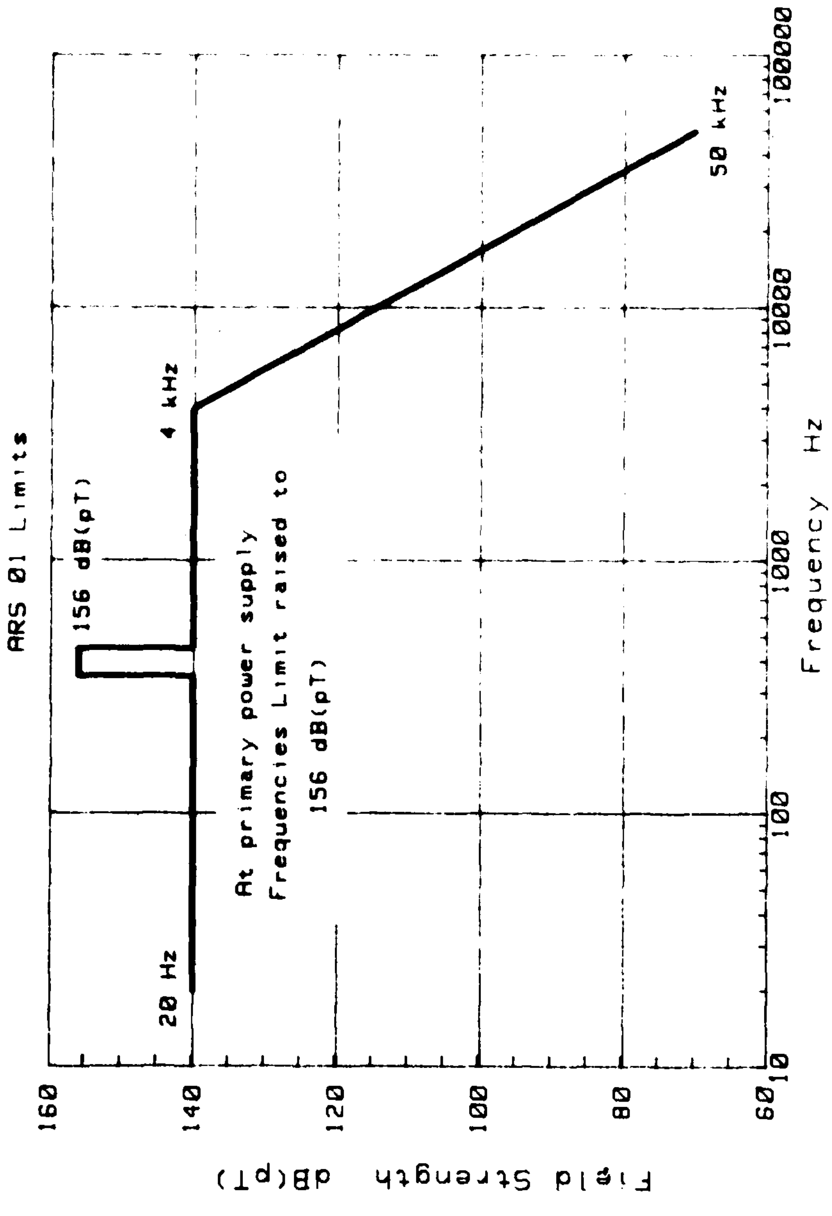


Figure 47 : Limit for Test Method ARS 01; Radiated Susceptibility Magnetic Field, 20 Hz to 50 kHz

SECTION 8.1

ARS 02 RADIATED SUSCEPTIBILITY, ELECTRIC FIELD 50 kHz to 18 GHz

1 Purpose

The purpose of this test is twofold:

(a) To ensure that the equipment under test does not exhibit any degradation of performance, malfunction or undesirable effects in the frequency range 50 kHz to 18 GHz when immersed in the specified electric field.

(b) In special circumstances, to record via a current probe, the rf current levels which are induced into selected EUT wiring looms (up to 1 GHz) in order to provide a means of correlation of results when the whole aircraft is subjected to rf electric fields and to allow comparison of loom currents in the radiating field with those obtained during the [illegible] test ([illegible] MHz). This is a special requirement to be called for by the Technical Authority in cases where the data obtained is specifically required in subsequent aircraft trials.

2 Applicability

The EUT including cable and interconnecting wiring are subject to this test method.

3 Test Set-Up

Section 6 should be studied before commencement of the test. Figure 48 shows a typical test set-up.

Care should be taken to ensure isolation of the test equipment from the rf electric field environment, with special attention given to filtering cableforms at the screened room wall and providing fibre-optic interfaces at the EUT to give susceptibility-free monitoring of the EUT's performance. The fibre-optic interfaces should be designed such that they could be utilised to monitor equipment performance when the whole aircraft is subjected to rf electric fields.

RF absorber material should be used to reduce screened room reflections whenever possible.

4 Test Method

Antennas, power amplifiers and signal generators shall be selected to produce the required field intensities at the specified frequencies to cover the area of the EUT. When the beam width of the antenna does not cover the EUT completely, multiple area scans shall be specified in the EMC Test Plan. The EMC Test Plan shall specify the orientation of the antennas to ensure that when polarised antennas are employed that both vertical and horizontal orientations are tested.

Each face of the EUT shall be probed with a loop to determine the localised area(s) of maximum susceptibility. The probe shall be orientated for maximum pick-up 50 mm from the surface of the EUT. (See Paragraph 6.28.3). Antennas shall be positioned at least 1 metre distance from the area of maximum susceptibility.

The guidance and methods in paragraph 6.28 shall be used for production and measurement of electric fields.

In instances where a parallel strip line antenna is used the calibration method shall be described in the approved EMC Test Plan.

No point of the field-generating and field measuring antennas shall be less than 1 metre to the wall, ceiling or floor of the enclosure or obstruction.

Where electric field strengths prohibit screened enclosure type testing application shall be made to the EMC Control Board to use alternative methods and sites.

The modulation requirements shall be as specified in section 6.23.

The field should be swept over the complete frequency band at gradually increasing levels to ensure the weakest points are measured.

If measurements of induced current are made in accordance with the test plan requirements the current probe shall be placed 50 mm from the backshell of the connector on the loom being measured.

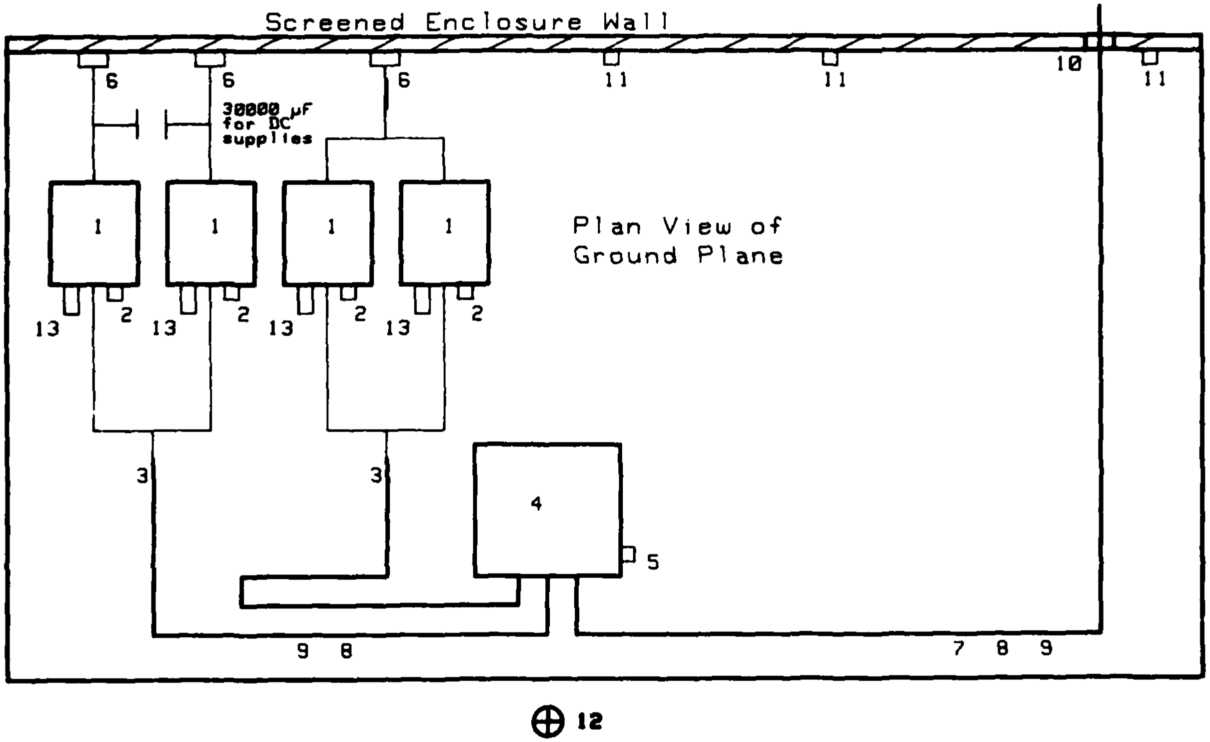
At frequencies above 1 GHz discontinuities in the screening of the EUT shall be presented to the transmitting antenna directly, i.e. turn the EUT so that numerical displays, CRT screens, LRU connectors etc are normal to the main lobe from the radiating antenna.

5 Test Limits

The EUT shall not be susceptible to cw or modulated signals of the frequency or amplitude as defined in Figure 49. When using modulated signals the amplitude shall be that indicated by the peak detector of an emi receiver.

The limit for the special pulse requirements in the radar band is a minimum of 5 X CW limit i.e. a minimum peak value as measured by an emi receiver of 100 V/m (see section 6.23).

NOTE - For systems with wiring feeding to or from external stores the limit should be a minimum of 6 dB (twice) above that shown in Figure 49. The actual level will be chosen by the technical authority and defined in the EMC Test Plan.



1. LISN and 10µF feedthrough capacitor
2. Bond to ground plane
3. EUT power leads, 1 metre total length separated at 300 mm from LISN
4. EUT situated with it's face 100 mm +/- 20 mm from front edge of ground plane, where possible
5. Bond to ground plane for EUT, as defined
6. Filtered power supply terminals at screened enclosure wall
7. EUT interconnecting lead; length as defined in Test Set-Up
8. Power leads and interconnecting leads to be situated 100 mm +/- 20 mm from edge of ground plane where possible
9. Power leads and interconnecting leads to be supported 50 mm above ground plane level via insulated stand-offs
10. Interconnecting lead to monitoring equipment/test set via feedthrough connectors or feedthrough filters
11. Ground plane dc bond to screened enclosure wall shall be less than 2.5 milliohms
12. Antennas positioned as in Para 6.28 and connected to amplifier via double shielded or semi-rigid co-axial cable
13. 50 ohm termination for LISN

Figure 48 : Typical Test Configuration for Test Method ARS 02; Radiated Electric Field, 50 kHz to 18 GHz

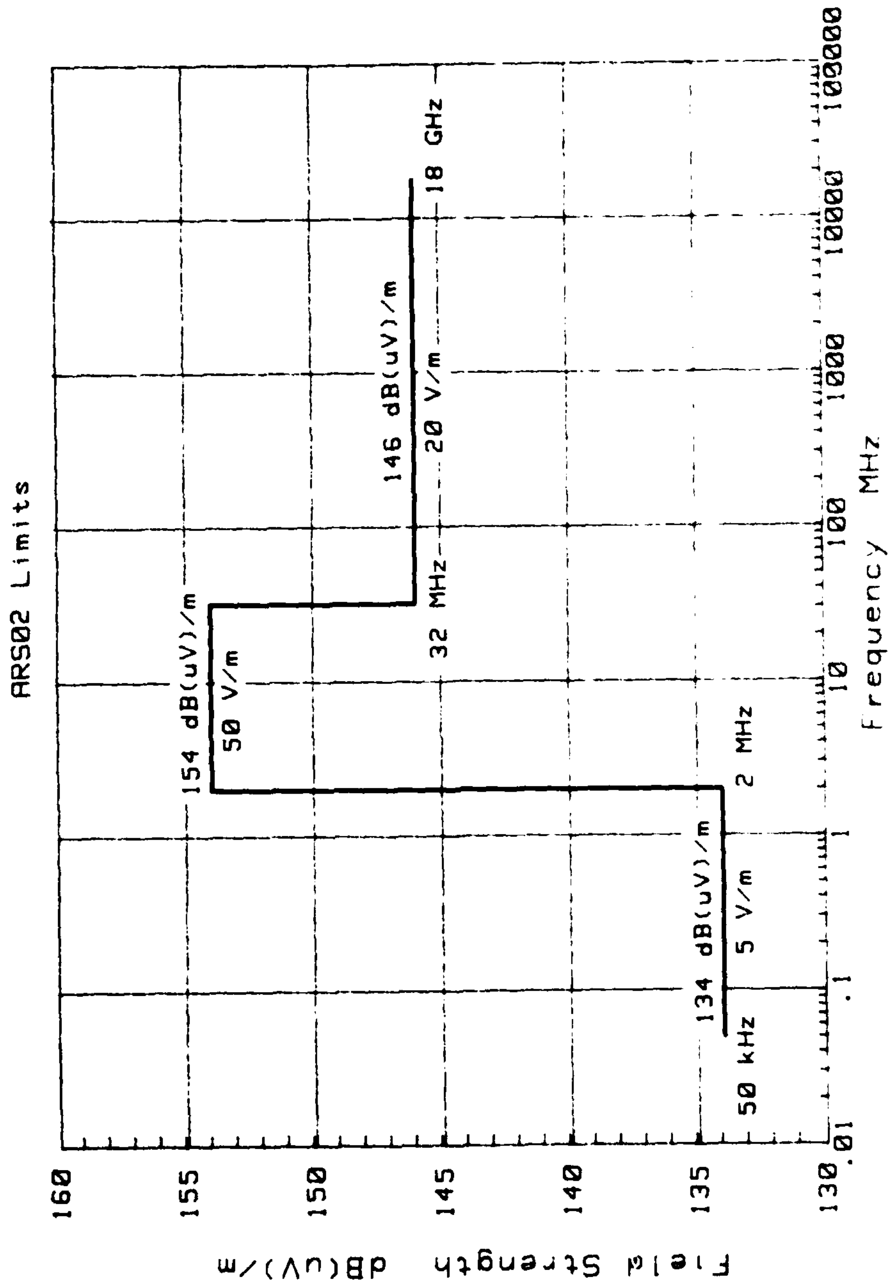


Figure 49 : Limit for Test Method ARS 02; Radiated Susceptibility, Susceptibility, 50 kHz to 18 GHz

8 ACKNOWLEDGEMENT

Acknowledgement is given to the other members of the Specifications sub-group for their efforts in producing this document: Mr B.Lewis AES23, Dr.K.Roger and Sq.Ldr.B.Harvey of A&AEE Boscombe Down. Acknowledgement is also given to Mr E.G.Stevens of ERA Techrology Ltd for his help in preparing the text and the drawings.

(b) Log-periodic Antenna: An antenna in which the length and spacing of the elements are in a logarithmic ratio.

(c) Conical Log-spiral Antenna (log-conical): An antenna formed from a continuous conductor wound in a spiral having logarithmic geometry.

BROADBAND DYNAMIC RANGE: The real-time dynamic range of a receiver (see dynamic range) in the presence of a broadband emission. The broadband dynamic range is always equal to or less than the narrowband dynamic range due to front-end saturation.

BROADBAND EMISSION: Emission which generates a spectrum of radio noise wider than the bandwidth of the measuring set. The measured values of such interference will, in general, depend on the type of voltmeter employed, i.e. quasi-peak or peak. Broadband peak values are usually expressed in terms of microvolts or microamperes per unit bandwidth.

CALIBRATION: The process by which measuring equipment indications are translatable to absolute units referred to one or more standards.

CONDUCTED: The coupling mode by which a voltage, current, or power is directly coupled with attenuation or gain from one network to another. In EMI, examples of conducted coupling are a hard-wire-to-hard-wire, or current probe or voltage probe coupling. One type of conducted coupling is through the powerline, signal or control leads, by which a potential intefering source may excite a potentially susceptible receptor.

CURRENT PROBE: A sensor which clamps around a wire and develops an emf from the magnetic field about the wire. This permits a quick connect/disconnect method for sampling the current in the wire at either power or radio frequencies. In the latter application, for EMI testing, the current probe drives a receiver and the transfer impedance is specific; viz, the ratio of output voltage to input current for a 50 ohm termination.

DECIBEL: A measure of the ratio of two powers, P_1 and P_2. Decibel (dB) is equal to 10*log (P_2/P_1). When impedances associated with both powers are equal, the voltage or current ratio in units of dB is 20 log (V_2/V_1), or 20*log (I_2/I_1).

dBm (decibels above 1 milliwatt): A standard unit of narrowband signal or interference power based on a reference of 1 milliwatt. Levels below 1 mW bear a negative sign before the dBm equivalent. For a 50 ohm reference resistance,

-107 dBm is equivalent to 0 dBuV (1 microvolt) developed across 50 ohm.

dBuV (decibels above 1 microvolt): A unit of measurement of narrowband signal or interference based on a reference of 1 microvolt. For a [illegible] ohm reference resistance.

0 dBuV (i.e. 1 microvolt) across 50 ohm is equivalent to -107 dBm

This is a standard voltage reference for most EMI/RFI measurements.

dBW (decibels above 1 watt): A standard unit of narrowband [illegible] interference power based on a reference of 1 watt. Levels below [illegible] bear a negative sign before the dBW equivalent.

NOTE: -107 dBm = -137 dBW [illegible]

AD-A188 867 RECOMMENDED TEST SPECIFICATION FOR THE ELECTROMAGNETIC 2/2
COMPATIBILITY OF A..(U) ROYAL AIRCRAFT ESTABLISHMENT
FARNBOROUGH (ENGLAND) N J CARTER NOV 85

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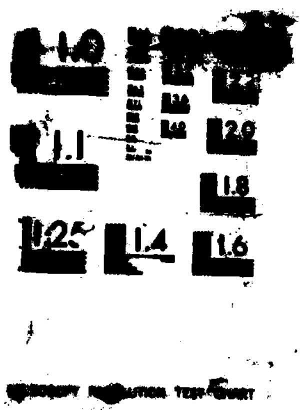
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APPENDIX A

EMI/EMC TERMS AND DEFINITIONS

AMBIENT EMISSIONS: The background level of electromagnetic energy emanating from sources other than an EUT such as atmospheric and manmade noise. The emissions which are present with the EUT de-energised and test equipment energised.

ANECHOIC CHAMBER: A microwave darkroom for performing radiated test measurements, usually above 200 MHz. The reflection coefficient (reflectivity) of the chamber walls is usually less than about 0.01 (40 dB) above some stated frequency, such as 1 GHz.

ANTENNA: A transducer which either launches rf power into space from a signal source, or intercepts arriving rf power transforming it into a signal in a receiver input transmission line.

ANTENNA COUNTERPOISE: A solid sheet-metal slab, a screen or a web which provides a ground reference plane for an antenna, such as an electric field rod. A counterpoise may be directly or capacitively coupled to earth ground.

ANTENNA CORRECTION FACTOR (for the calculation of field strength): That factor which, when applied to the voltage at the input terminals of the measuring instrument, yields the electric field strength in volts/metre or the magnetic field strength in amperes/metre. To this factor should be added any mismatch and interconnecting cable losses to determine the overall correction factor.

BANDWIDTHS: The extent of a continuous range of frequencies over which the gain of the receiver or amplifier does not differ from its maximum value by more than a specified amount.

PASSBAND FILTER: An electrical device which passes signals over a defined frequency spectrum and rejects or attenuates signals outside this spectrum. The passband is usually limited to the 3 dB bandwidth.

BAND-REJECTION FILTER: An electrical device which rejects signals over a defined band (the stop band) and which passes signals outside this band with little attenuation.

BONDING: The process of mechanically connecting together metal parts so that they make low impedance electrical contact for d.c. and all a.c. frequencies.

BROADBAND: A relative or qualitative term used as a general measure of bandwidth occupancy in terms of being relatively narrow or broad. For some components, broadband may mean more than 20 percent bandwidth; for others it may mean one octave, one decade (10:1 frequency range) or other value. Further, the term broadband occasionally refers to either the amplitude or VSWR considerations, as applicable.

BROADBAND ANTENNAS: Antennas designed to operate over a substantial range of frequencies in such a manner that there is a relatively small variation of their characteristics over this range. Examples are:

(a) Biconical Antenna: An antenna formed by two similar opposed cones having a common axis and fed at the vertices, which are adjacent.

dBuV/MHz (decibels above 1 microvolt per Megahertz): A unit of measurement of broadband electromagnetic interference. It is equal to the RMS sine-wave microvolts (unmodulated) applied to the input of the measuring receiver at its centre frequency that will result in a peak detector response equal to that from the interference pulse being measured, divided by the impulse bandwidth of the circuit in Megahertz.

DECADE: A frequency ratio of 10 to 1, such as 1 to 10 kHz or 30 to 300 MHz. One decade equals 3.32 octave.

DEVIATIONS FROM NORMAL: An undesired change in the standard reference output occurring during a susceptibility test.

DYNAMIC RANGE: The real time range of signal accommodation in a receiver amplitude-measuring instrument expressed in dB. This range does not permit the use of rf attenuators. Dynamic range is generally limited at low-signal levels to either internal receiver noise or levels required to drive a detector. It is limited at the high levels at the last stage of an IF amplifier or post-detector amplifier.

Sometimes either receiver front-end saturation or intermodulation limit the highest signal level accommodation (cf broadband and narrowband dynamic range).

ELECTROMAGNETIC COMPATIBILITY (EMC): The ability of electrical and electronic equipment, sub-systems to share the electromagnetic spectrum and perform their desired functions without unacceptable degradation from or to the environment in which they exist.

EQUIPMENT UNDER TEST (EUT): The black box, equipment, sub-system or other device where performance is being measured. See also Test Sample.

EMISSION SPECTRUM: Amplitude-versus-frequency relation of a time modulated carrier. For transmitters, it may also include the effect of the antenna radiation pattern.

ELECTROMAGNETIC INTERFERENCE (EMI): Any electric, magnetic or electromagnetic disturbance, phenomenon, or emission which causes or is likely to cause unacceptable response, malfunction, or degradation of performance of any avionic equipment, sub-system or system, or unacceptable degradation of the environment.

EMITTER: A generic term used to identify an intentional man-made radiator such as the antenna and transmitter associated with a radar, communications, navigation, telemetry, or jammer. In EMI the term is also applied to unintentional radiators such as a piece of wire, a connector, a slot, or virtually any device which is capable of radiation.

FIELD STRENGTH: In radio wave propagation, the magnitude of a component of specified polarisation of the electric or magnetic field.

NOTE:

The electromagnetic field due to a conductor carrying an oscillatory current is complex and contains radiation nd induction ($1/r$, $1/r^2$, $1/r^3$) terms. The radiation field will obey a $1/r$ law, whilst the induction fields will obey $1/r^2$ nd $1/r^3$ laws, where r is the distance from source. At distances of less than a wavelength from the conductor, the induction fields are usually dominant and measurements of both the the magnetic and electric fielsds are desirable. The results should be expressed in appropriate units, (i.e. amperes per metre or volts per metre).

FILTER: A device which provides signal transmission over defined band(s) of frequency and rejection over other band(s). Some basic types of filters are low-pass, high-pass and band-rejection filters.

FREQUENCY-SELECTIVE VOLTMETER: A tunable, frequency-selective receiver used as two-terminal voltmeter. For example, such a receiver may be used as a narrowband-conducted interference meter or a field-intensity meter.

HARMONIC: An integer multiple of a fundamental frequency.

HIGH-PASS FILTER: An electrical device which passes signals above a specified frequency, generally its 3 dB transmission-loss or cutoff frequency, and which rejects signals below this frequency.

IMPEDANCE (referring to Networks): The ratio of voltage to current.

IMPEDANCE (referring to space or media): The ratio of the electric to the magnetic-field. In the far field, it is equal to 377 ohm. In the near field it may be either greater or less than this depending upon the source characteristics.

IMPULSE BANDWIDTH: The average bandwidth of the impulse response curve. It is approximately equal to 1.05 times the bandwidth at 6 dB maximum response.

IMPULSE: An isolated disturbance or a pulse of duration short compared with any repetition period. Regularly repeated impulses of constant amplitude will generate a spectrum of discrete frequencies (Fourier components) each separated in frequency by an amount equal to the repetition frequency.

IMPULSE GENERATOR: A special-purpose, signal generator used for either broadband calibration or network transmission-loss measurements. It has the properties of generating pulses of extremely short duration, typically less than 1 nanosecond, for use up to 1 GHz.

Other values are also used depending upon frequency of interest.

INSERTION LOSS: The ratio of the power delivered to a load before the insertion of a network, such as a filter, to the power after network insertion. The insertion loss is often expressed in dB and is used to describe the ratio of the corresponding voltages, provided terminating impedance have not changed with the network insertion.

INTERFERENCE: The manifestation of an emission at a receptor which causes degradation in its normal performance, the term,is often used to describe emanations from an emitting source without regard to whether it may degrade the performance of the receptor. This rationale is based on prior knowledge that emissions of certain amplitudes will cause a degradation of performance.

INTERFERENCE-FREE MEASUREMENT AREA: An area sufficiently free from emissions and site reflections so that EMI test measurement results are not adversely affected. INTERNAL NOISE: Electromagnetic disturbances originating in the circuitry of electronic equipment, such as shot noise, thermal agitations, and power-line hum.

INTERNAL NOISE LEVEL (INL): The total receiver noise available at the detector of the measuring device, referred back to the input terminals.

An indication of the level is obtained on the measuring equipment output display when a matched load is connected to the receiver input.

KEYDOWN: For EMI antenna-conducted measurements, the test specimen transmitter is a transmit mode. Not applicable to receivers.

KEYUP: Transmitters in a standby or ready-to-transmit mode. Applied to receivers in a ready-to-receive mode.

LINE IMPEDANCE STABILISING NETWORK (LISN): A network inserted in the power supply lead of the apparatus to be tested which provides a specified measuring impedance for interference voltage (or current) measurements and isolates the apparatus from the power source at radio frequencies.

LOW-PASS FILTER: An electrical device which passes signals from d.c. up to a specified frequency, generally the 3 dB transmission-loss or cutoff frequency and which rejects signals above this frequency.

NARROWBAND DYNAMIC RANGE: The real-time dynamic range of a receiver (see dynamic range) in the presence of a narrowband emission. The narrowband dynamic range is always equal to or greater than the broadband dynamic range.

NARROWBAND EMISSION: A type of emission which manifests itself at a discrete frequency or a range of frequencies narrower than the measurement bandwidths. Narrowband emission generally arises from the harmonics produced by equipment generating continuous oscillations.

NOTE:

A rectangular pulse train which would normally be regarded as broadband can manifest itself as narrowband providing that the generation of impulses is fairly regular and that the pulse repetition frequency is comparable with or greater than the bandwidth of the measuring equipment.

OCTAVE: A frequency ratio of 2 to 1, such as from 1 to 2 kHz or 500 to 1000 MHz; 3.32 octaves equal one decade.

ONE METRE ROD ANTENNA: A 1 metre equivalent rod or whip antenna used to field-strength measurements. For the purpose of EMI specification tests, the rod is loaded and some effort to impedance-match it to the receiver has been made.

PEAK DETECTOR: A detecting device which removes the signal carrier, has a risetime less than the reciprocal of the widest IF amplifier bandwidth and which stretches the signal long enough to permit a meter, record, or plotter to come up to full response before dumping.

POLARISATION: A term used to describe the orientation of the electric-field vector of a radiated field. POWER DENSITY: A measure of the radiated power from an emitter at an intercept point measured in units of watts/m^2, or dB/m^2.

PULSED CW: A carrier modulated by one of several types of pulse modulations. Resulting emissions have a spectrum occupancy, which appears either narrowband or broadband depending upon both the pulse duration and the bandwidth.

RADIATION: The propagation of a signal or interference from an emitter other than by conduction.

RADIATED INTERFERENCE: Propagated energy which produces either malfunctioning or degradation of electronic equipment performance.

RANDOM NOISE: A wideband signal characterised by arbitrary amplitude, frequency and phase relations.

RECEIVER: An electromagnetic instrument which transmits low-intensity, intercepted signals into high-level signals capable of driving a speaker, cathode-ray tube, meter, recorder, plotter, or other display or readout device.

RESOLUTION: A measure of the ability of an instrument to distinguish between two signals closely spaced in either frequency or time. For a receiver, the frequency resolution approximates the 3 dB bandwidth of the last predetector IF amplifier. For a recorder, the time resolution approximates the reciprocal of the 3 dB frequency response.

SHIELDED ENCLOSURE: A screened or solid metallic housing designed expressly for the purpose of isolating the internal and external electromagnetic environments. The purpose is to prevent outside ambient electromagnetic fields from causing performance degradation and/or to prevent emissions from causing interference to outside activities.

SLIDEBACK CIRCUITS: To obtain a true peak signal reading, one method is to use a slideback circuit. Such a circuit consists of an adjustable bias on a detector which blocks signal voltages less than the required to overcome the bias. The bias is adjusted manually until the output indication just disappears. The level is then calibrated by impulse generator substitution.

SPIKE: A high-frequency oscillatory variation from the controlled steady-state level of a characteristic. It results from the high-frequency currents of a complex waveform produced when reactive loads are switched.

SURGE: A variation from the controlled steady-state level of a characteristic resulting from the inherent regulation of the electrical power supply system and remedial action by the associated control and protection equipment.

SUSCEPTIBILITY: The unacceptable responses, degradation or malfunction of equipment, sub-systems or systems.

SUB-HARMONIC: A fractional multiple of a fundamental signal.

TEST SAMPLE: The blackbox, equipment, sub-system or other device whose performance is being measured.

THRESHOLD OF SUSCEPTIBILITY: That level of interference at which the equipment under test begins to show an undesirable response.

TRANSFER IMPEDANCE: The ratio of the output voltage to an input current vs frequency for defined source and terminating impedances. The term is used to define the correction factor to be used with current probes.

TRANSIENT: The short-term changing condition of a characteristic that goes beyond the steady-state limits and returns to the steady-state limits within a specified time period. Transients are commonly divided into surges and spikes.

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